SCOOP

SAR Altimetry Coastal and Open Ocean Performance

Product Specification Document (PSD) Level-1B, Level-2, RDSAR, WTC

Deliverable D2.3

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22.12.16	0.9			Pre-release version without RDSAR content
14.02.17	1.1	All	multiple	V1.1 issued after ESA Review
31.03.17	1.2	4.5		Minor correction to input filename
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06.06.19	1.3(b)	5		Updates for RDSAR
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Control Document

Process	Name	Date
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For SCOOP team		
For ESA		

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1 Introduction

1.1 Scope

The scope of this document is to identify and specify the formats of the SCOOP [AD. 1] Test Data Set Products: Level 1 (L1B-S and L1B), Level 2 (L2), RDSAR, and Wet Troposphere Correction.

The algorithms used to generate the Test Data Sets are given in the Algorithm Theoretical Basis Document [AD. 2], the processor configuration options in the Processing Options Configuration Document [AD. 3], and the Input / Output Definitions in the Input Output Definitions Document [AD. 4].

The SCOOP Test Data Sets are accessible on request from the SCOOP project manager (d.cotton@satoc.eu), and are described in the SCOOP Project Data Pages (http://www.satoc.eu/projects/SCOOP/data.html).

1.2 Document Organisation

This document is organised in five main sections,

- Section 1, with a short introduction defining the scope of this report.
- Section 2, some general definitions, written by isardSAT.
- Section 3, describing the L1B/ L1B-S products, written by isardSAT.
- Section 4, describing the L2 products, written by STARLAB.
- Section 5, describing the RDSAR products, written by TU-Delft.
- Section 6, describing the Wet Troposphere Correction Products, written by University of Porto.

1.3 Acronyms

AD	Applicable Document
AGC	Automatic Gain Control
AOCS	Attitude and Orbit Control Subsystem
ATBD	Algorithm Theoretical Baseline Documents
CAL1	Calibration Mode 1
CAL2	Calibration Mode 2
CF	Climate Forecast
COASTALT	ESA Project on Coastal Altimetry
CP4O	Cryosat Plus for Oceans
CryoSat (-2)	ESA altimeter satellite for polar ice investigations
CS2	Cryosat-2
DComb	Data Combination
DDP	Delay Doppler Processor
DMP	Data Management Plan
ECMWF	European Centre for Medium Range Weather Forecasting
ERA	ECMWF ReAnalysis
ESA	European Space Agency
FBR	Full Bit Rate
FFT	Fast Fourier Transform
GIM	Global Ionosphere Maps

GNSS	Global Navigation Satellite System
GPD+	GNSS Derived Path Delay Plus
HRM	High Resolution Mode
IODD	Input Output Definition Document
ISP	Instrument Source Packet
ITRF	International Terrestrial Reference Frame
L1A	Output file with geo-located bursts of Ku echoes. All calibrations are applied. Each record contains 1 SAR burst of calibrated and aligned echoes
L1B-S	Output file with fully processed and calibrated SAR complex echoes, arranged in stacks after slant range correction and prior to echo multi-look.
L1B	Output file with fully calibrated pulse limited power echoes for LRM and fully calibrated multi-looked power echoes (SAR)
L2	Level 2 - Output file with the main geophysical parameters estimated by the retracker (i.e. SSH, SWH, Pu,...)
LRM	Low Rate Mode
MWR	Microwave Radiometer
NetCDF	(Network common data form) – Set of software libraries and (self -describing, machine independent) data formats.
OA	Objective Analysis
PLRM	Pseudo Low Resolution Mode
POCCD	Processing Options Configuration Document
PSD	Product Specification Document
RADS	Radar Altimeter Database System (NOAA/EUMETSAT/TUDelft)
RD	Reference Document
RDSAR	Reduced resolution SAR mode data (used to generate PLRM)
ROI	Region of Interest
SAMOSA	SAR altimetry Mode Studies and Applications
SAR	Synthetic Aperture Radar
SatOC	Satellite Oceanographic Consultants
Sentinel-3, S-3	ESA Remote sensing mission in the Copernicus programme
Sigma0	Radar Backscatter at nadir
SRAL	Synthetic Aperture Radar Altimeter on Sentinel-3
SCOOP	SAR Altimetry Coastal and Open Ocean Performance
SI- MWR	Scanning Imaging - MicroWave Radiometer
SL_cci	Sea level Climate Change Initiative
SoW	Statement of Work
SSB	Sea State Bias
SSM/I	Special Sensor Microwave Imager
SSM/IS	SSMI/I Sounder
SSH	Sea Surface Height
SWH	Significant Wave Height
TAI	International Atomic Time (from Temps Atomique International)
TN	Technical Note
TUDelft	Delft University of Technology
USO	Ultra Stable Oscillator
UPorto	University of Porto
UTC	Coordinated Universal Time
WTC	Wet Troposphere Correction

1.4 References

1.4.1 Applicable Documents

AD. 1 **SCOOP – S**AR Altimetry **C**oastal & **O**pen **O**cean **P**erformance Exploitation and Roadmap Study. Sentinel 3 For Science – SAR Altimetry Studies Study 2 – Coastal Zone and Open Ocean Study. Proposal, January 2015.

AD. 2 SCOOP. Algorithm Theoretical Baseline Document (ATBD)- WP1000. SCOOP_D1.3_ATBD, v1.7, 12/06/19.

AD. 3 SCOOP. Processing options Configuration Control Document (POCCD) - WP1000. SCOOP_D1.4_POCCD, v1.4, 04/02/19.

AD. 4 SCOOP. Input Output Definitions Document (IODD) - WP2000. SCOOP_D2.1_IODD, v1.4, 12/06/19.

1.4.2 Reference Documents

RD. 1 EUMETSAT/ESA. Sentinel-3 PDGS: File Naming Convention, ref. GMES-S3GS-EOPG-TN-09-0009, issue 1.3, 7th November 2012.

RD. 2 ACS/ESA. CryoSat Ground Segment IPF L1B: Product Specification Format, ref. CS-RS-ACS-GS-5106, issue 6.4, 30th Abril 2015.

RD. 3 ESA. SRAL Input/Output Definition Document for Product Level 1A/1B-S, ref. S3-TN-ESA-SR-0433, issue 1.4, 13th March 2014.

RD. 4 ESA. Product Data Format Specification- SRAL/MWR Level 1 & 2 Instrument Products, ref. S3IPF.PDS.003, issue 2.0, 30th September 2015.

RD. 5 CryoSat Product Handbook, ESRIN-ESA and Mullard Space Science Laboratory – University College London, April 2012.

RD. 6 Sentinel-3 Core PDGS Instrument Processing Facility (IPF) Implementation. Product Data Format Specification- SRAL/MWR Level 1 & 2 Instrument Products. Ref: S3IPF.PDS.003, Issue: 2.0, September 2015.

RD- 7 Salvatore Dinardo, "Guidelines for reverting Waveform Power to Sigma Nought for CryoSat-2 in SAR mode," ref: XCRY-GSEG-EOPS-TN-14-0012.

RD- 8 Scharroo, Remko, RADS User Manual, version 4.3.5., 2 May, 2019: https://github.com/remkos/rads

RD- 9 Scharroo, Remko, RADS Data Manual, version 4.3.5., 2 May, 2019: https://github.com/remkos/rads

2 General Definitions

2.1 General definitions

In the following section a set of general definitions are described for the sake of clearness and completeness.

- Level-1B-S products contain geo-located, calibrated, azimuth processed complex echoes after geometric correction application arranged in stacks and before power averaging (multi-looking). Relevant ancillary data (e.g., beam angles, calibration information, statistical description of stack,...) is included.
- Level-1B products contain geo-located and fully calibrated multi-looked high-resolution (fully SAR-processed) Ku-band power echoes.

2.2 Variable Types

Table 2-1 Variable Types

Variable Type	Description	Range
uc	8-bit unsigned integer (ubyte)	0 to 255
sc	8-bit signed integer (byte)	-128 to 127
us	16-bit unsigned integer	0 to 65535
ss	16-bit signed integer	-32768 to 32767
ul	32-bit unsigned integer	0 to 4294967295
sl	32-bit signed integer	-2147483648 to 2147483647
sll	64-bit signed integer	-9223372036854775808 to 9223372036854775807
fl	32-bit single precision floating point	1.17549e-38 (min) 3.4028e+38(max)
do	64-bit single precision double point	2.22e-308(min) 1.79e+308(max)

2.3 NetCDF Format File

The NetCDF format has been lately widely used to provide remote sensing data, especially in the oceanographic framework. The main advantages of such encapsulating data format are its flexibility in the definition/creation/access of data, its transversal capability to share machine/platform-independent data and their self-describing characteristics. Thanks to such potentialities and easiness in data sharing such format has been selected to provide L1A, L1B and L2 data for the Sentinel-3 data.

A NetCDF file is composed by the following elements:

- **Dimensions:** used to represent a real physical dimension (e.g., time, latitude, longitude, or height) or to index other quantities (e.g., number of waveforms or samples). A dimension has both a name and a length.
- **Variables:** used to store the data in a NetCDF file. A variable corresponds to an array of values of the same type. Each variable is completely defined by its name, data type and shape (described by the list of dimensions). A scalar value is defined as a 0-dimensional array. A variable can contain also related attributes, which can be added, deleted or modified once the variable has been created.
- **Attributes:** used to keep information about the data (metadata). Generally, they provide information about a specific variable. These are identified by the name of the variable, jointly with the name of the attribute (e.g., units, scale factor, or offset to be added).
- **General attributes**: used to provide a global description of the dataset as a whole.

An example of a NetCDF for the L1B product is:

```
netcdf file:/ /test_data/SAR_Phase2/L1B/north_sea/2013/data/
CR2_SR_1_SRA____20131231T214551_20131231T214713_20180926T165915_isd.nc {
  dimensions:
    time_l1b_echo_sar_ku = 1804;
    max_multi_stack_ind = 256;
    echo_sample_ind = 256;
    space_3D = 3;
  variables:
    double time_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :standard_name = "time";
      :long_name = "UTC Seconds since 2000-01-01 00:00:00.0+00:00 (Ku-band)";
      :calendar = "Gregorian";
      :units = "seconds";
      :comment = "time at surface of the SAR measurement(multilooked waveform).";

    short UTC_day_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Days since 2000-01-01 00:00:00.0+00:00 (Ku-band)";
      :units = "day";
      :comment = "days elapsed since 2000-01-01. To be used to link with L1 and L2
records (time_l1b provides the number of seconds since 2000-01-01).";

    double UTC_sec_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Seconds in the day UTC, with microsecond resolution (Ku-band)";
      :units = "seconds";
      :comment = "seconds in the day. To be used to link L1 and L2 records
(time_l1b provides the number of seconds since 2000-01-01).";

    int lat_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :add_offset = 0.0; // double
      :standard_name = "latitude";
      :long_name = "latitude (positive N, negative S) (Ku-band)";
      :units = "degrees";
      :scale_factor = 1.0E-6; // double
      :comment = "Latitude of measurement [-90, +90]: Positive at Nord, Negative at
South";

    int lon_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
```

```
      :standard_name = "longitude";
      :long_name = "longitude (positive E, negative W) (Ku-band)";
      :units = "degrees";
      :scale_factor = 1.0E-6; // double
      :add_offset = 0.0; // double
      :comment = "longitude of measurement [-180, +180]: Positive at East, Negative
at West";

    int alt_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "altitude of satellite";
      :units = "meters";
      :scale_factor = 1.0E-4; // double
      :add_offset = 700000.0; // double
      :comment = "Altitude of the satellite Centre of Mass";

    short orb_alt_rate_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "orbital altitude rate";
      :units = "m/s";
      :scale_factor = 0.01; // double
      :add_offset = 0.0; // double
      :comment = "Instantaneous altitude rate at the Centre of Mass";

    int satellite_mispointing_l1b_sar_echo_ku(time_l1b_echo_sar_ku=1804,
space_3D=3);
      :long_name = "Mispointing angle, measures by STRs: [1] Pitch, [2] Roll, [3]
Yaw (Ku-band)";
      :units = "degrees";
      :scale_factor = 1.0E-7; // double
      :comment = "Attitude mispointing, measured by STRs and post-processed by AOCS
or by ground facility. The 3 components are given according to the \'space_3D\'
dimension: [1] Roll, [2] Pitch, [3] Yaw. This variable includes the \"mispointing
bias\" given by the variable mispointing_bias_ku. Note: nominal pointing is at
satellite nadir (antenna perpendicular to ellipsoid) and corresponds to: roll =
pitch = yaw = 0";

    double x_pos_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Satellite altitude-x component";
      :units = "meters";

    double y_pos_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Satellite altitude-y component";
      :units = "meters";

    double z_pos_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Satellite altitude-z component";
      :units = "meters";

    double x_vel_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Satellite velocity-x component";
      :units = "m/s";

    double y_vel_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Satellite velocity-y component";
      :units = "m/s";

    double z_vel_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
```

```
      :long_name = "Satellite velocity-z component";
      :units = "m/s";

    int seq_count_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Sequence count";
      :comment = "Value the closest in time to the reference measurement";

    byte oper_instr_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Operating instrument";
      :flag_values = "0b,1b";
      :flag_meanings = "A,B (Sentinel-3) / Nominal, Redundant (CryoSat-2)";
      :comment = "Value the closest in time to the reference measurement. For
Sentinel-3: Instrument A stands for SRAL Nominal and instrument B stands for SRAL
Redundant";

    byte SAR_mode_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "SAR mode identifier";
      :comment = "Value the closest in time to the reference measurement";
      :flag_values = "0b,1b,2b (Sentinel-3) / 0b, 1b (Cryosat-2)";
      :flag_meanings = "closed_loop, open_loop, open_loop_fixed_gain (Sentinel-3) /
closed, open (CryoSat-2)";

    long h0_applied_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Applied altitude command H0";
      :units = "3.125/64*1e-9 seconds";
      :comment = "Value the closest in time to the reference measurement";

    short cor2_applied_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Applied altitude command COR2";
      :units = "3.125/1024*1e-9 seconds";
      :comment = "Value the closest in time to the reference measurement";

    byte agccode_ku_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "AGCCODE for Ku band";
      :units = "dB";
      :comment = "Value the closest in time to the reference measurement";

    byte surf_type_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Altimeter surface type";
      :flag_values = "0,1,2,3";
      :flag_meanings = "open_ocean or semi-enclosed_seas, enclosed_seas or lakes,
continental_ice, land,Transponder";
      :comment = "Value the closest in time to the reference measurement";

    int range_ku_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Corrected range for Ku band";
      :units = "meters";
      :scale_factor = 1.0E-4; // double
      :add_offset = 700000.0; // double
      :comment = "Reference range corrected for USO frequency drift and internal
path correction";

    int uso_cor_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "USO frequency drift correction";
      :units = "meters";
      :scale_factor = 1.0E-4; // double
```

```
      :add_offset = 0.0; // double
      :comment = "Value the closest in time to the reference measurement";

    int int_path_cor_ku_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Internal path correction for Ku band";
      :units = "meters";
      :scale_factor = 1.0E-4; // double
      :add_offset = 0.0; // double
      :comment = "Value the closest in time to the reference measurement";

    int range_rate_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Range rate";
      :units = "meters";
      :scale_factor = 0.001; // double
      :add_offset = 0.0; // double
      :comment = "Value the closest in time to the reference measurement";

    int scale_factor_ku_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Scaling factor for sigma0 evaluation";
      :units = "dB";
      :scale_factor = 0.01; // double
      :add_offset = 0.0; // double
      :comment = "This is a scaling factor in order to retrieve sigma-0 from the
L1B waveform. It includes antenna gains and geometry satellite - surface. It is not
applied to the L1B waveforms";

    int nb_stack_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Number of waveforms summed in stack (contributing beams:
effective number of looks or beams from stack used in multilooking; if beams with
all samples set to zero not to be included in multilooking they are accordingly not
accounted in this number; if there are some gaps in-between mask set to zero all
the samples related to those beams and they will not be contributing to the
multilooking )";
      :units = "count";

    int nb_stack_start_stop_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Number of waveforms in stack (considering the number of
beams/looks from start and stop beams: they correspond to the first and last beams
at edges of stack). If there exist gaps in between or beams discarded by the mask
(stack_mask_range_bin_l1b_echo_sar_ku_name equal -1): these in-between beams are
considered anyway in the \"nb_stack_start_stop_l1b_echo_sar_ku\". This number of
beams will be useful to construct accordingly the modelled stack for retracking.";
      :units = "count";

    short look_angle_start_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Angle of first look  (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
      :comment = "Look angle of the first contributing look (non-0 weight) to the
L1B waveform";

    short look_angle_stop_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Angle of last look  (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
```

```
      :comment = "Look angle of the last contributing look (non-0 weight) to the
L1B waveform";

    short doppler_angle_start_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Angle of first look  (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
      :comment = "Doppler angle of the first contributing look (non-0 weight) to
the L1B waveform";

    short doppler_angle_stop_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Angle of last contributing look  (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
      :comment = "Doppler angle of the last contributing look to the L1B waveform";

    short pointing_angle_start_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Angle of first contributing look  (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
      :comment = "Pointing angle of the first contributing look to the L1B
waveform";

    short pointing_angle_stop_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Angle of last contributing look  (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
      :comment = "Pointing angle of the last contributing look to the L1B
waveform";

    int skew_stack_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Skewness of stack";
      :units = "count";
      :scale_factor = 1.0E-6; // double
      :add_offset = 0.0; // double
      :comment = "Skewness of the Gaussian that fits the integrated power of the
looks within a stack. The skewness indicates how symmetric or asymmetric the power
within the stack is";

    int kurt_stack_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Kurtosis of stack";
      :units = "count";
      :scale_factor = 1.0E-6; // double
      :add_offset = 0.0; // double
      :comment = "Kurtosis of the Gaussian that fits the integrated power of the
looks within a stack. Kurtosis is a measure of peakiness";

    long stdev_stack_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Gaussian Power fitting: STD wrt look angle (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
      :add_offset = 0.0; // double
      :comment = "Standard deviation of the Gaussian that fits the integrated power
of the looks within a stack. It is given with respect to the look angle. The width
at -3dB of this Gaussian can be retrieved the following way: width_3db =
2*sqrt(2*ln2)*gaussian_fitting_std";
```

```
    short gaussian_fitting_centre_look_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Gaussian Power fitting: centre wrt look angle (Ku-band)";
      :units = "rad";
      :scale_factor = 1.0E-6; // double
      :add_offset = 0.0; // double
      :comment = "Position of the center of the Gaussian that fits the integrated
power of the looks within a stack, with respect to look angle";

    int beam_form_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Flag on beam formation quality in stack";
      :units = "percent";
      :scale_factor = 0.01; // double
      :comment = "Beam formation quality in percentage: percentage of beams in the
stack that are processed with the exact generation of beams";

    int altimeter_clock_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Altimeter clock (Ku-band)";
      :units = "Hz";
      :add_offset = 3.2E8; // double
      :scale_factor = 1.0E-9; // double
      :comment = "This is the actual altimeter clock.";

    long pri_lrm_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "PRI converted into seconds (Ku-band)";
      :units = "seconds";
      :scale_factor = 1.0E-12; // double
      :comment = "The \'Pulse Repetition Interval\'. PRI is constant within all
received pulses in a radar cycle, but it can change within consecutive radar
cycles.";

    int i2q2_meas_ku_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804,
echo_sample_ind=256);
      :long_name = "SAR\tPower Echo waveform: scaled\t0-65535 (Ku-band)";
      :units = "count";
      :comment = "The SAR L1B Power waveforms is a fully calibrated, high
resolution, multilooked waveform. It includes: (a) all calibrations, which have
been applied at L1A, (b) SAR processor configuration according to the L1B
processing flags, (c) final scaling, given in the variable
\'waveform_scale_factor_l1b_echo_sar_ku\', in order to best fit the waveform into 2
bytes";

    short stack_mask_range_bin_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804,
max_multi_stack_ind=256);
      :long_name = "Range bin stack mask ";
      :units = "count";
      :scale_factor = 2.0; // double
      :comment = "The zero-mask applied to the stack before multilooking. It
includes the geometry corrections mask to avoid wrapping effects. Each element of
the mask refers to a look in the stack and indicates the index of the first sample
set to zero. When a specific look or beam shall not be considered at all in the
multilooking the value is set to -1. The first nb_stack_start_stop_l1b_echo_sar_ku
elements of the mask are valid, while the remaining ones are filled with -1.";

    float waveform_scale_factor_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
```

```
      :long_name = "Echo Scale Factor, to convert from [0-65535]\tto Power at\tantenna\tflange";
      :units = "Watt/#";
      :comment = "The L1B waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B waveform into Watt, is applied as follows: power_waveform_watt(ku_rec, Ns) = i2q2_meas_ku_l1b_echo_sar_ku(ku_rec, Ns) * waveform_scale_factor_l1b_echo_sar_ku(ku_rec)";

    short zero_padding_l1b_echo_sar_ku;
      :long_name = "Oversampling factor used in the range compression (FFT)";
      :units = "count";
      :comment = "the ground processor can apply an oversampling factor, providing a waveform_sampling = nominal_sampling / range_oversampling_factor. Note that the altimeter range resolution is fixed and given by the chirp bandwidth";

    int dry_tropo_correction_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Dry Tropospheric Correction";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int wet_tropo_correction_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Wet Tropospheric correction";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int inverse_baro_correction_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Inverse Barometric Correction";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int Dynamic_atmospheric_correction_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Dynamic Atmospheric Correction";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int GIM_iono_correction_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "GIM Ionospheric Correction";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int model_iono_correction_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Model Ionospheric Correction";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int ocean_equilibrium_tide_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Ocean Equilibrium Tide";
      :units = "meters";
      :scale_factor = 0.001; // double
```

```
      :comment = "Value the closest in time to the reference measurement";

    int long_period_tide_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Long Period Ocean Tide";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int ocean_loading_tide_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Ocean Loading Tide";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int solid_earth_tide_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Solid Earth Tide";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

    int geocentric_polar_tide_l1b_echo_sar_ku(time_l1b_echo_sar_ku=1804);
      :long_name = "Geocentric Polar Tide";
      :units = "meters";
      :scale_factor = 0.001; // double
      :comment = "Value the closest in time to the reference measurement";

  // global attributes:
  :creation_time = "_20180926T165915_";
  :Conventions = "netcdf4";
  :mission_name = "CR2";
  :altimeter_sensor_name = "RX_1";
  :gnss_sensor_name = "Not available";
  :doris_sensor_name = "Not available";
  :acq_station_name = "Kiruna";
  :first_meas_time = "31-DEC-2013 21:46:25.620096";
  :last_meas_time = "31-DEC-2013 21:47:47.611589";
  :xref_altimeter_level0 =
"CS_OPER_SIR1SAR_0__20131231T214551_20131231T214713_0001.DBL   ";
  :xref_altimeter_orbit =
"CS_OPER_MPL_ORBPRE_20131231T001000_20140130T001000_0001.EEF   ";
  :xref_doris_USO = "CS_OPER_AUX_DORUSO_20100411T040029_20150325T034019_0001.DBL
";
  :xref_altimeter_ltm_sar_cal1 =
"CS_OFFL_SIR1SAC11B_20141231T115925_20150401T115925_C100.DBL   ";
  :xref_altimeter_ltm_ku_cal2 = "cs_users_characterization_C002.nc";
  :xref_altimeter_ltm_c_cal2 = "Not available for CR2";
  :xref_altimeter_characterisation =
"CS_OPER_AUX_IPFDBA_20100701T000000_99999999T999999_0001.EEF   ";
  :semi_major_ellipsoid_axis = "6378137";
  :ellipsoid_flattening = "0.003352810664747";
  :orbit_phase_code = "2";
  :orbit_cycle_num = "+007";
  :orbit_REL_Orbit = "+00022";
  :orbit_ABS_Orbit_Start = "019785";
  :orbit_Rel_Time_ASC_Node_Start = "2003.811401";
  :orbit_ABS_Orbit_Stop = "019785";
```

```
    :orbit_Rel_Time_ASC_Node_Stop = "2085.802979";
    :orbit_Equator_Cross_Time = "31-DEC-2013 21:12:26.765515";
    :orbit_Equator_Cross_Long = "-0161956221";
    :orbit_Ascending_Flag = "D";
    :Start_Lat = "+0058738512";
    :Start_Long = "+0013011472";
    :Stop_Lat = "+0053800526";
    :Stop_Long = "+0012100065";
}
```

2.4 File Naming Convention

The file names proposed for the products are based on the ESA files naming convention, specifically for the Sentinel-3 mission (for complete details on the naming convention please refer to [RD- **1**]). In the following the structure for the SRAL source instrument is considered, adapted to include the new intermediate product SRF:

MMM_SR_***L_TTTTTT_yyyymmddThhmmss_YYYYMMDDTHHMMSS_YYYYMMDDTHHMMSS_ <in stanceID>_GGG_<class_ID>***

Table 2-2 Logical file name elements

Naming Element	Size in characters	Description
MMM	3	**Mission ID** Uppercase letters or digits: S3A = Sentinel-3A S3B = Sentinel-3B S3_ = for both Sentinel-3A and -3B CR2 = for CryoSat-2
L	1	**Processing level** Consists of 3 digits or 3 underscores "_" if processing level does not apply. **"0"** for Level-0 **"1"** for Level-1 **"2"** for Level-2

Naming Element	Size in characters	Description
TTTTTT	6	**Data Type ID** Consists of 6 characters, either uppercase letters or digits or underscores "_". The suffix "AX " in the last 2 digits indicates an auxiliary data. The suffix "BW" in the last 2 digits indicates a browse product. **SRAL data** Level 0 **"SRA___"** = observation ISPs **"CAL___"** = calibration ISPs Level 1 **"SRA_A_"** = Level 1A products containing complex echoes sorted and calibrated **"SRA_BS"** = Level 1B-S products, including the regular Level 1B product, enriched with complex I&Q echoes after geometric corrections and prior to multi-looking **"SRA___"** =Level 1B products including the SAR average measurements (20 Hz) **"CAL___"** = calibration parameters Level 2 **"LAN___"** = 1-Hz and 20-Hz waveforms parameters over land **"WAT___"** = 1-Hz and 20-Hz waveforms parameters over water
yyyymmddThhmmss	15	**Data start time** Initial validity or sensing time Format: . 8 char., all digits, for the date: "yyyymmdd", year, month, day . 1 uppercase T: "T" . 6 char., all digits, for the time: "hhmmss", hour, minutes, seconds
yyyymmddThhmmss	15	**Data stop time** Initial validity or sensing time Format: . 8 char., all digits, for the date: "yyyymmdd", year, month, day . 1 uppercase T: "T" 6 char., all digits, for the time: "hhmmss", hour, minutes, seconds
yyyymmddThhmmss	15	**Creation date** Date of file creation Format: . 8 char., all digits, for the date: "yyyymmdd", year, month, day . 1 uppercase T: "T" 6 char., all digits, for the time: "hhmmss", hour, minutes, seconds
Instanceid	17	The instance id fields include the following cases, applicable as indicated: . Instance ID for the instrument data products disseminated in "stripes": Duration,"_", cycle number, "_", relative orbit number,"_", 4 underscores "_" DDDD_CCC_LLL_____ . Instance ID for the instrument data products disseminated in "frames": Duration, "_", cycle number, "_", relative orbit number, "_", frame along track coordinate DDDD_CCC_LLL_FFFF . Instance ID for the instrument data products disseminated in "tiles": 17 characters, either letters or digits or undersocres or any combination of them to identify the geographical area covered by the tile[1].
GGG	17	**Product Generating Centre** isd = isardSAT processing facility/archive

[1] For Sentinel-3 there are specific pre-defined areas of interest. In a similar fashion and for the processed C-FBR CryoSat-2 data, specific region of interest definition can be included in this field based on the regions of interest (ROIs) defined in the technical note.

3 L1B Format Specification

This section provides a detailed view of the L1B product, describing all the NetCDF variables

3.1 L1B NetCDF format

L1B products are complaint with the NetCDF-4 format, following the variables convention names provided in Sentinel-3 format product specifications [RD- **4**]. A NetCDF file contains dimensions, variables, attributes and global attributes as described in Section 2.3 The global attributes description can be found in Section 3.3

Table 3-1 Dimensions for the Level 1B product

Dimension Name	Description	Value
time_l1b_echo_sar_ku	number of Ku bursts (L1A ECHO_SAR Ku measurements) in the file, with a frequency of 80 Hz[2]	# of Ku waveforms
echo_sample_ind	Number of samples in a waveform	128*zp[3]
max_multi_stack_ind	Maximum number of multilook beams per stack	256

[2] For CryoSat the frequency is around 85 Hz (85 bursts in one second).
[3] Zp refers to zero padding or range oversampling and it is set to 1,2,4,... as indicated in the processing options configuration file in [AD. 3].

3.2 L1B Products Variables

Tables Thematically Grouped

Table 3-2 L1B NetCDF product variables[4]

Variable Name	Description	Range or Value	Type	Dimension
Time				
Time_l1b_<xx>[5]	UTC: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Standard_name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	time		1
Long_name	Seconds since 2000-01-01 00:00:00.0			1
Calendar	Maximum number of multilook beams per stack	Gregorian		1
Units	Unit Name	seconds		1
Comment	time at surface of the SAR measurement(multilooked waveform)			1
UTC_day_l1b<xx>	day UTC: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Long_name	Days since 2000-01-01 00:00:00.0 (Ku-band)			1
Units	Unit Name	day		1
Comment	days elapsed since 2000-01-01. To be used to link with L1 and L2 records (time_l1b provides the number of seconds since 2000-01-01)			1
UTC_sec_l1b<xx>	seconds in the day UTC: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Long_name	Days since 2000-01-01 00:00:00.0 (Ku-band)			1
Units	Unit Name	seconds		1
Comment	seconds in the day. To be used to link L1 and L2 records (time_l1b provides the number of seconds since 2000-01-01)			1

[4] Variables originally defined in Sentinel-3 L1B product are marked in yellow, variables not defined in Sentinel-3 and inherited from Sentinel-6 are marked in blue, while variables available in FBR of CryoSat-2 and not included in Sentinel-3 L1B product are marked in green.

[5] For improved readability of parameter names a <xx> extension is used referring to echo_sar_ku.

Variable Name	Description	Range or Value	Type	Dimension
Orbit and attitude				
lat_l1b_<xx>	latitude: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Standard_name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	time		1
Long_name	latitude (positive N, negative S) (Ku-band)			1
Units	Unit Name	degrees		1
Scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
Add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Latitude of measurement [-90, +90]: Positive at North, Negative at South			1
lon_l1b_<xx>	longitude: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Standard_name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	time		1
Long_name	longitude (positive E, negative W) (Ku-band)			1
Units	Unit Name	degrees		1
Scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
Add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Latitude of measurement [-180, +180]: Positive at East, Negative at West			1
alt_l1b_<xx>	Altitude of satellite: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-4		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	700000		1
Comment	Altitude of the satellite Centre of Mass			1
orb_alt_rate_l1b_<xx>	Orbital altitude rate: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	m/s		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-2		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Instantaneous altitude rate at the Centre of Mass			1

satellite_mispointing_l1b_<xx>	Satellite mispointing: l1b_echo_sar_ku_mode		sl	3*time_l1b_echo_sar_ku
Long_name	Mispointing angle, measures by STRs: [1] Roll, [2] Pitch, [3] Yaw (Ku-band)			1
Units	Unit name	degrees		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-7		1
Comment	Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility. The 3 components are given according to the "space_3D" dimension: [1] Roll, [2] Pitch, [3] Yaw. This variable includes the "mispointing bias" given by the variable mispointing_bias_ku. Note: nominal pointing is at satellite nadir (antenna perpendicular to ellipsoid) and corresponds to: roll = pitch = yaw = 0			1
satellite_mispointing_l1b_<xx>	Satellite mispointing: l1b_echo_sar_ku_mode		sl	3*time_l1b_echo_sar_ku
Long_name	Mispointing angle, measures by STRs: [1] Roll, [2] Pitch, [3] Yaw (Ku-band)			1
Position / Velocity				
x_pos_l1b_<xx>	Satellite altitude-x component: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Units	Unit name	m		1
y_pos_l1b_<xx>	Satellite altitude-y component: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Units	Unit name	m		1
z_pos_l1b_<xx>	Satellite altitude-z component: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Units	Unit name	m		1
x_vel_l1b_<xx>	Satellite altitude-x component: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Units	Unit name	m		1
y_vel_l1b_<xx>	Satellite velocity-y component: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Units	Unit name	m		1
z_vel_l1b_<xx>	Satellite velocity-z component: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Units	Unit name	m		1
Navigation Bulletin				
seq_count_l1b_l1b_<xx>	Sequence count: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	Count		1
Comment	Value the closest in time to the reference measurement			1
Instrument and Tracking				Sequence count: l1b_echo_sar_ku_mode
oper_instr_l1b_<xx>	Operating instrument: l1b_echo_sar_ku_mode		sc	time_l1b_echo_sar_ku

flag_values	Flag Values	0b,1b		1
Flag_meanings	Flag meanings	A,B (Sentinel-3) / Nominal, Redundant (CryoSat-2)		1
Comment	Value the closest in time to the reference measurement. For Sentinel-3: Instrument A stands for SRAL Nominal and instrument B stands for SRAL Redundant			1
SAR_mode_l1b_<xx>	SAR mode identifier: l1b_echo_sar_ku_mode		sc	time_l1b_echo_sar_ku
flag_values	Flag Values	0b,1b,2b (Sentinel-3) / 0b, 1b (Cryosat-2)		1
Flag_meanings	Flag meanings	closed_loop, open_loop, open_loop_fixed_gain (Sentinel-3) / closed, open (CryoSat-2)		1
Comment	Value the closest in time to the reference measurement			1
H0, COR2 and AGC				
h0_applied_l1b_<xx>	Applied altitude command H0: l1b_echo_sar_ku_mode		ul	time_l1b_echo_sar_ku
Units	Unit name	3.125/64*10^-9 s		1
Comment	Value the closest in time to the reference measurement			1
Cor2_applied_l1b_<xx>	Applied altitude command COR2: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	3.125/1024*10^-9 s		1
Comment	Value the closest in time to the reference measurement			1
agccode_ku_l1b_<xx>	AGCCODE for Ku band: l1b_echo_sar_ku_mode		sc	time_l1b_echo_sar_ku
Units	Unit name	dB		1
Comment	Value the closest in time to the reference measurement			1
Surface Type				
surf_type_l1b_<xx>	Altimeter Surface type: l1a_echo_sar_ku_mode		sc	time_l1b_echo_sar_ku
Long_name	Altimeter surface type			1

flag_values	Flag Values	0,1,2,3		1
flag_meanings	Flag meanins	open_ocean or semi-enclosed_seas, enclosed_seas or lakes, continental_ice, land		1
Comment	Value the closest in time to the reference measurement			1
Altimeter Range				
range_ku_l1b_<xx>	Corrected range for Ku band: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-4		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	700000		1
Comment	Reference range corrected for USO frequency drift and internal path correction			1
uso_cor_l1b_<xx>	USO frequency drift correction: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-4		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Value the closest in time to the reference measurement			1
int_path_cor_ku_l1b_<xx>	Internal path correction for Ku band: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-4		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Value the closest in time to the reference measurement			1
range_rate_l1b_<xx>	Internal path correction for Ku band: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1

Comment	Value the closest in time to the reference measurement			1
Sigma0 scaling				
scale_factor_ku_l1b_<xx>	Scaling factor for sigma0 evaluation: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	dB		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-2		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	This is a scaling factor in order to retrieve sigma-0 from the L1B waveform. It includes antenna gains and geometry satellite - surface. It is not applied to the L1B waveforms			1
Stack Characterisation				
nb_stack_l1b_<xx>	Number of waveforms summed in stack: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	count		1
nb_stack_start_stop_l1b_<xx>	Number of looks/beams potentially contributing in stack: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	count		1
Comment	Number of waveforms in stack (considering the number of beams/looks from start and stop beams: they correspond to the first and last beams at edges of stack. If option of discarding beams with all-zeros samples these correspond to the first and last beams with non-all zeros samples (if there exist gaps in between: mask setting to zero all samples, these in-between beams are considered anyway in the "nb_stack_start_stop_l1b_echo_sar_ku"), otherwise they correspond to the very first and very last beam in the stack). This number of beams will be useful to construct accordingly the modelled stack for retracking.			Comment
look_angle_start_l1b_<xx>	Angle of first look/beam: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	Radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
Comment	Look angle of the first contributing look/beam (non-0 weight) to the L1B waveform (Look angle is defined as angle between nadir satellite and the given surface for that beam or look)			1
look_angle_stop_l1b_<xx>	Angle of last look/beam: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	Radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1

Comment	Look angle of the last contributing look/beam (non-0 weight) to the L1B waveform (Look angle is defined as angle between nadir satellite and the given surface for that beam or look)			1
doppler_angle_start_l1b_<xx>	Angle of first look/beam: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	Radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
Comment	Doppler angle of the first contributing look/beam (non-0 weight) to the L1B waveform (Doppler angle is defined as angle between satellite velocity vector and the vector from the satellite to the surface for that beam or look)			1
doppler_angle_stop_l1b_<xx>	Angle of last look/beam: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	Radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
Comment	Doppler angle of the last contributing look/beam (non-0 weight) to the L1B waveform (Doppler angle is defined as angle between satellite velocity vector and the vector from the satellite to the surface for that beam or look)			1
pointing_angle_start_l1b_<xx>	Angle of first look/beam: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	Radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
Comment	Pointing angle of the first contributing look/beam (non-0 weight) to the L1B waveform (Pointing angle is defined as angle between satellite boresight and the vector from the satellite to the surface for that beam or look)			1
pointing_angle_stop_l1b_<xx>	Angle of last look/beam: l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Units	Unit name	Radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
Comment	Pointing angle of the last contributing look/beam (non-0 weight) to the L1B waveform (Pointing angle is defined as angle between satellite boresight and the vector from the satellite to the surface for that beam or look)			1
skew_stack_l1b_<xx>	Skewness of stack: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	count		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1

Comment	Skewness of the Gaussian that fits the integrated power of the looks within a stack. The skewness indicates how symmetric or asymmetric the power within the stack is			1
kurt_stack_l1b_<xx>	Kurtosis of stack: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	count		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Kurtosis of the Gaussian that fits the integrated power of the looks within a stack. Kurtosis is a measure of peakiness			1
stdev_stack_l1b_<xx>	Standard deviation of stack (Ku-band): l1b_echo_sar_ku_mode		ul	time_l1b_echo_sar_ku
Long_name	Long name	Gaussian Power fitting: STD wrt look angle (Ku-band)		
Units	Unit name	radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Standard deviation of the Gaussian that fits the integrated power of the looks within a stack. It is given with respect to the look angle. The width at -3dB of this Gaussian can be retrieved the following way: width_3db = 2*sqrt(2*ln2)* stdev_stack_l1b_<xx>			1
gaussian_fitting_centre_look_l1b_<xx>	centre wrt look angle (Ku-band): l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku
Long_name	Long name	Gaussian Power fitting: centre wrt look angle (Ku-band)		
Units	Unit name	radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Position of the center of the Gaussian that fits the integrated power of the looks within a stack, with respect to look angle			1
gaussian_fitting_centre_pointing_l1b_<xx>	centre wrt pointing angle (Ku-band): l1b_echo_sar_ku_mode		ss	time_l1b_echo_sar_ku

Long_name	Long name	Gaussian Power fitting: centre wrt look angle (Ku-band)		
Units	Unit name	radians		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Position of the center of the Gaussian that fits the integrated power of the looks within a stack, with respect to pointing angle			1
beam_form_l1b_<xx>	Flag on beam formation quality in stack: l1b_echo_sar_ku_mode		us	time_l1b_echo_sar_ku
Units	Unit name	percent		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-2		1
Comment	Beam formation quality in percentage			1
Altimeter Engineering Variables				
altimeter_clock_l1b_<xx>	Altimeter clock: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku
Units	Unit name	Hz		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-9		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	320e+6		1
Comment	This is the actual altimeter clock.			1
pri_lrm_l1b_l1b_<xx>	Pulse repetition interval: l1b_echo_sar_ku_mode		do	time_l1b_echo_sar_ku
Units	Unit name	s		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-12		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	The "Pulse Repetition Interval". PRI is constant within all received pulses in a radar cycle, but it can change within consecutive radar cycles.			1
Waveform Variables				
i2q2_meas_ku_l1b_<xx>	I2+Q2 measurement for Ku band: l1b_echo_sar_ku_mode		sl	time_l1b_echo_sar_ku*echo_sample_ind

Long_name	Long name	SAR Power Echo waveform: scaled 0-65535 (Ku-band)		
Units	Unit name	count		1
Comment	The SAR L1B Power waveforms is a fully calibrated, high resolution, multilooked waveform. It includes: (a) all calibrations, which have been applied at L1A, (b) SAR processor configuration according to the L1B processing flags, (c) final scaling, given in the variable "waveform_scale_factor_l1b_echo_sar_ku", in order to best fit the waveform into 2 bytes			1
waveform_scale_factor_l1b_<xx>	Waveform scale factor: l1b_echo_sar_ku_mode		fl	time_l1b_echo_sar_ku
Long_name	Long name	Echo Scale Factor, to convert from [0-65535] to Power at antenna flange		
Units	Unit name	Watt/count		1
Comment	The L1B waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B waveform into Watt, is applied as follows: power_waveform_watt(ku_rec, Ns) = i2q2_meas_ku_l1b_echo_sar_ku (ku_rec, Ns) * waveform_scale_factor_l1b_echo_sar_ku(ku_rec)			1
stack_mask_range_bin_l1b_<xx>	Range bin stack mask: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku* max_multi_stack_ind
Units	Unit name	count		1
scale_factor	The data must be multiplied by this factor after reading	Zp factor		1
Comment	Before the stack is multi-looked, the different looks are cropped according to these value. For each look, the number of the first cropped sample is provided. The scale factor is equal to the range_oversampling_factor			1
stack_mask_range_bin_l1b_<xx>	Range bin stack mask: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku* max_multi_stack_ind
zero_padding_l1b_l1b_<xx>	Zero padding: l1b_echo_sar_ku_mode		fl	1
	Geophysical Corrections[6]			
dry_tropo_correction_l1b_<xx>	Dry Tropospheric Correction: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1

Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
wet_tropo_correction_l1b_<xx>	Wet Tropospheric correction: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1

[6] From the Sentinel-3 PSD no geophysical corrections are included in the L1B product. However, when processing the CryoSat-2 data and taking into account that such information is made available in the FBR product, the corresponding geophysical corrections will be included in the L1B (taking the one closest in time to the reference measurement- burst just above the surface)

inverse_baro_correction_l1b_<xx>	Inverse Barometric Correction: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
Dynamic_atmospheric_correction_l1b_<xx>	Dynamic Atmospheric Correction: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
GIM_iono_correction_l1b_<xx>	GIM Ionospheric Correction: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
model_iono_correction_l1b_<xx>	Model Ionospheric Correction: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
ocean_equilibrium_tide_l1b_<xx>	Ocean Equilibrium Tide: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
long_period_tide_l1b_<xx>	Long Period Ocean Tide: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1

ocean_loading_tide_l1b_<xx>	Ocean Loading Tide: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
solid_earth_tide_l1b_<xx>	Solid Earth Tide: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
geocentric_polar_tide_l1b_<xx>	Geocentric Polar Tide: l1b_echo_sar_ku_mode		uc	time_l1b_echo_sar_ku
Units	Unit name	m		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-3		1
Comment	Value the closest in time to the reference measurement: for the burst just above the surface			1
Processing Parameters				
zero_padding_l1b_<xx>	Oversampling factor used in the range compression (FFT): l1b_echo_sar_ku_mode		uc	1
Units	Unit name	count		1
Comment	the ground processor can apply an oversampling factor, providing a waveform_sampling = nominal_sampling / range_oversampling_factor. Note that the altimeter range resolution is fixed and given by the chirp bandwidth. A value of 1 means no zero-padding has been applied.			1

3.3 L1B Global Attributes

Table 3-3: L1B Global Attributes[7]

Attribute Name	Format	Description
creation_time	String	UTC Date of the NetCDF file creation (YYYY-MM-DD HH:MM:SS.mmmmmm)
conventions	String	netCDF convention
mission_name	String	Name of the mission
altimeter_sensor_name	String	Name of the altimeter sensor
gnss_sensor_name	String	Name of the GNSS sensor
doris_sensor_name	String	Name of the DORIS sensor
acq_station_name	String	Identification of the acquisition station :
first_meas_time	String	UTC Date of the first measurement of the data set (YYYY-MM-DD HH:MM:SS.mmmmmm)
last_meas_time	String	UTC Date of the first measurement of the data set (YYYY-MM-DD HH:MM:SS.mmmmmm)
xref_altimeter_level0	String	Name of the altimeter level 0 data file
xref_altimeter_orbit	String	Name of the file containing the Orbit Data
xref_doris_uso	String	Name of the file containing the DORIS-derived USO frequency
xref_altimeter_ltm_sar_cal1	String	Name of the LTM file containing the SAR mode CAL1 parameters
xref_altimeter_ltm_ku_cal2	String	Name of the LTM file containing the Ku-band CAL2 parameters
xref_altimeter_ltm_c_cal2[8]	String	Name of the LTM file containing the C-band CAL2 parameters
xref_altimeter_characterisation	String	Name of the altimeter characterisation data file
semi_major_ellipsoid_axis	String	Semi-major axis of the reference ellipsoid (meters)
ellipsoid_flattening	String	Flattening coeffcient of the reference ellipsoid
orbit_phase_code	String	Phase code: phase letter or number (If not used set to X)
orbit_cycle_num	String	Cycle number (set to +000 if not used)
orbit_REL_Orbit	String	Relative Orbit Number at sensing start time. If not used set to +00000
orbit_ABS_Orbit_Start	String	Absolute Orbit Number at Product Start time
orbit_Rel_Time_ASC_Node_Start	String	Relative time since crossing ascending node time relative to start time of data sensing (seconds)
orbit_ABS_Orbit_Stop	String	Absolute Orbit Number at Product Stop Time
orbit_Rel_Time_ASC_Node_Stop	String	Relative time since crossing ascending node time relative to stop time of data sensing (seconds)
orbit_Equator_Cross_Time	String	UTC Time of Equator crossing at the ascending node of the sensing start time (dd-MMM-yyyy hh:mm:ss.uuuuuu)
orbit_Equator_Cross_Long	String	Longitude of Equator Crossing at the ascending node of the sensing start time (positive East, 0 =Greenwich) referred to WGS84. (10e-6 degrees)
orbit_Ascending_Flag	string	Orbit Orientation at the sensing start time (A: ascending, B: descending)

[7] Attributes originally defined in Sentinel-3 L1B product are marked in yellow, while some parameters defined in the header of FBR of CryoSat-2 and requested by UPorto are included as global attributes and marked in green.

[8] For CryoSat processed data this attribute will be set to not available since no C-band operation is considered in the mission.

Attribute Name	Format	Description
Start_Lat	string	Latitude of the first record in the measurement data set, defined as positive North (10e-6 degrees)
Start_Long	string	Longitude of the first record in the measurement data set, defined as positive East (10e-6 degrees)
Stop_Lat	string	Latitude of the last record in the measurement data set, defined as positive North (10e-6 degrees)
Stop_Long	string	Longitude of the last record in the measurement data set, defined as positive East (10e-6 degrees)

4 L2 Product Specification

4.1 Product definitions

The main outputs of the L2 files are the geophysical parameters estimated by the re-tracker (i.e. Sea Surface Height (SSH), Significant Wave Height (SWH), and σ_o). In addition general parameters (e.g. Epoch time, Latitude, Longitude, ...), or the main corrections (e.g. range corrections due to tidal effects, range corrections due to atmospheric effects, etc) are included. The main variables are listed and defined below.

4.1.1 Time

Time at surface of the SAR measurement (multilooked waveform) expressed in seconds. The reference Time for the TAI Datation is 01/01/2000 00:00:00.

4.1.2 Day

Days elapsed since 01/01/2000 00:00:00, expressed in days.

4.1.3 Seconds

Seconds in the day UTC, with a microsecond resolution.

4.1.4 Latitude

Latitude interpolated from the orbit at the exact time recorded in the time stamp. Expressed in degrees (from -90 to 90), positive in the North, and negative in the South. The latitude is measured from the reference ellipsoid at nadir to the satellite centre of gravity.

4.1.5 Longitude

Longitude interpolated from the orbit at the exact time recorded in the time stamp. Given in degrees (from -180 to 180). Positive longitudes are used in the East, and negative in the West. The longitude is measured from the reference ellipsoid at nadir to the satellite centre of gravity.

4.1.6 Altitude

The distance of the satellite centre of mass above the reference ellipsoid. Expressed in meters.

4.1.7 Altitude rate

The instantaneous altitude rate at the satellite centre of mass derived from the orbit, expressed in m/s.

4.1.8 X_vel, y_vel, and z_vel

Refers to the satellite velocity vector components (x, y, and z) given in the International Terrestrial Reference Frame (ITRF), expressed in m/s.

4.1.9 Mispointing angle

The mispointing angle is the angle between the antenna pointing (i.e. the direction of the actual beam), and the nadir direction (normally defined by the roll, pitch and yaw). The mispointing angles are measured by the STR's, and post-processed by AOCS or by the ground facility.

4.1.9.1 Roll

The rotation around the side-to-side axis (relative to the X axis).

4.1.9.2 Pitch

The rotation around the front-to-back axis (relative to the Y axis).

4.1.10 Range

The range is defined as the one-way distance from the satellite to the surface point, expressed in meters. The range stored in the L2 file has included the USO frequency drift and internal path corrections.

4.1.11 USO

Refers to the USO frequency drift, measured in meters. The USO correction factor is usually defined as the ratio between the nominal and the modelled values.

4.1.12 Internal Path correction

The internal path correction accounts for the biases that the electronic systems can introduce (normally fixed biases that can be characterized during the calibration), and fluctuations biases that can be due to different issues, e.g. different heating around the orbit. The internal path corrections are expressed in meters.

4.1.13 Automatic Gain Control (AGC)

Automatic Gain Control expressed in dBs is used to keep the signal level as constant as possible.

4.1.14 Scale factor sigma

Is a scaling factor applied in order to retrieve the σ_o from the L1B Waveform. It is expressed in dBs, and includes contributions from the antenna gains and satellite geometry.

4.1.15 Surface type

The surface type is a flag specifying which kind of surface the altimeter observes, since the radar echo response will be affected by the kind of surface. Four different cases are defined.

- Open ocean or semi-enclosed sea.
- Enclosed sea or lakes.
- Continental ice.
- Land.

4.1.16 Dry tropospheric correction.

The dry tropospheric correction is required to compensate for the effect on the range of the dry gas component of the atmosphere. It is expressed in meters (typical values range from 1.7 to 2.5 m).

4.1.17 Wet tropospheric correction.

The wet tropospheric correction is required to compensate for the effect on the range of liquid water in the atmosphere (mainly water vapour). It is expressed in meters (typical values range from 0 to 50 cm).

4.1.18 Inverse barometric correction.

The inverse barometric correction is required to compensate for the variations in the sea surface height as a consequence of the atmospheric pressure variations. Is expressed in meters, typical values range from -15 to 15 cm.

4.1.19 Dynamic Atmospheric correction.

The dynamic atmospheric correction is required to compensate for the variations in the sea surface height as a consequence of the atmospheric pressure and winds. It is expressed in meters, typical values range from -15 to 15 cm.

4.1.20 Ionospheric correction.

The ionospheric correction (also called ionospheric bias correction), are required to compensate the bias introduced by the free electrons in the Earth's ionosphere. It is expressed in meters, and typical values are ranging from 0.06 to 0.12m. Two different variables related to the ionospheric corrections are included.

- GIM Ionospheric correction, derived from the Global Ionospheric Map (GIM).
- Model ionospheric correction, based on the Bent model is an alternative to the GIM ionospheric correction model. The Bent model is based on the knowledge of the solar activity index, such as sunspot numbers.

4.1.21 Ocean Equilibrium tide.

Range correction for the effects of local tides. Is expressed in meters, and typical values range from -50 to 50 cm.

4.1.22 Long Period Ocean tide.

Range correction, to compensate for the effects of the tides due to the Sun. Expressed in meters, typical values range from -50 to 50 cm.

4.1.23 Ocean Load tide.

Range correction, where deformation of the Earth's crust due to the weight of the overlying ocean tides is compensated. Is expressed in meters, and typical values range from -2 to 2 cm.

4.1.24 Solid Earth tide.

Range correction, where deformation of the Earth due to tidal forces from the Sun and Moon are accounted. Expressed in meters, typical values are range from -30 to 30 cm.

4.1.25 Geocentric Polar tide.

Range correction, where the long-period distortion of the Earth's crust caused by variations in centrifugal force is removed. Expressed in meters, typical values are range from -2 to 2 cm.

4.1.26 Sea Surface Height (SSH).

Is the Sea Surface Height computed in SAR mode, and expressed in meters. This first computation does not include any of the corrections listed above.

4.1.27 Sea Surface Height (SSH) with correction.

Is the Sea Surface Height computed in SAR mode, and expressed in meters, after applying the different corrections. These corrections for ocean includes,

- Tides:
  - Ocean equilibrium tides.
  - Long period equilibrium ocean tides.
  - Ocean loading tides.
  - Solid Earth tides.
  - Geocentric polar tides.
- Atmosphere:
  - Dry troposphere correction.
  - Wet troposphere correction.
  - Ionospheric correction (based on the GIM ionospheric correction i.e. GIM_iono)..
  - Dynamic atmospheric correction.

Is important to note that sea state bias corrections are not included at present.

4.1.28 Significant Wave Height (SWH).

The Significant Wave Height is the average wave height (through to crest), of the one-third largest waves. In the retracker it is computed as four times the standard deviation of the surface elevation ($4\sigma_z$). The units are meters.

4.1.29 Misfit.

MISFIT represents the quality of the fit between the L1B waveform and the retracker modelled waveform. The MISFIT is computed as the root mean square of sum of the residuals, scaled by the number of bins in the waveform,

$$MISFIT = 100 * \sqrt{\frac{1}{N}\sum_{0}^{N\text{-}1}(residual)^2}$$

where residuals are

$$residual = \left(model\text{-}data(bin_i: bin_n)\right)/\max\left(data(bin_i: bin_n)\right)$$

model represents the waveform obtained by the SAMOSA retracker, and *data* the real waveform.

4.2 Variable types

Variable Type	Description	Range
Double	64-bit double precision floating point	2.22 e-308 (min) 1.79e308 (max)

4.3 Content of the L2 products

The netCDF file is composed by the following elements:

- **Dimensions:** used to represent a real physical dimension (e.g. time, latitude, longitude, etc).
- **Variables:** used to store the data in the netCDF files. A variable corresponds to an array of values of the same type. Each variable is completely defined by its name, size, dimension, data type, and attributes (e.g. long name, units, comments).

The Level 2 products includes a range of geophysical quantities derived from the L1b products and the retracker, orbital and altitude information (e.g. latitude, longitude, altitude, altitude rate, etc), and geophysical correctios (both tides (e.g. ocean tide, long period equilibrium ocean tide, etc), and atmosphere (e.g. dry tropospheric correction, wet tropospheric corrections, etc)). The different variables contain the 20-Hz Ku band, and 1 Hz- Ku band measurements, where the 1-Hz measurements are built within the L2 processing from a reference time-lag and a fixed duration between consecutive measurements.

4.4 L2 Products variables

In Table 4-1 the main variables encountered in the L2 files are listed.

Table 4-1 L2 NetCDF product variables (starts next page)

Variable Name	Description	Range or Value	Type	Dimension
	Time			
Time_20 Hz	**Time UTC:**		**s**	**time**
Standard _name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	time		1
Long_name	UTC Seconds since 2000-01-01 00:00:00.0+00:00 (Ku-band) at 20 Hz			1
Calendar		Gregorian		1
Units	Unit name	seconds		1
Comment	Time at surface of the SAR measurement (multi-looked waveform)			1
Time_1 Hz	**Time UTC:**		**s**	**time**
Standard _name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	time		1
Long_name	UTC Seconds since 2000-01-01 00:00:00.0+00:00 (Ku-band) at 1 Hz			1
Calendar		Gregorian		1
Units	Unit name	seconds		1
Comment	Time at surface of the SAR measurement (multi-looked waveform)			1
Day	**Day UTC**		**s**	**time**
Long_name	Days since 2000-01-01 00:00:00.0+00:00 (Ku-band)			1
Units	Unit name	seconds		1
Comment	Days elapsed since 2000-01-01. To be used to link with L1 and L2 records (time_l1b provides the number of seconds since 2000-01-01)			1
Sec	**Day UTC**		**s**	**Time**
Long_name	Seconds in the day UTC, with microsecond resolution (Ku-band)			1
Units	Unit name	seconds		1
Comment	Seconds in the day. To be used to link L1 and L2 records (time_l1b provides the number of seconds since 2000-01-01)			1
	Orbit and attitude			
Latitude_20Hz	**Latitude**		**do**	**Time**
Long_name	Latitude (positive N, negative S) (Ku-band) at 20Hz			1

Units	Unit name	Degree		1
Comment	Latitude of measurement [-90, +90]: Positive at North, Negative at South			1
Latitude_1Hz	**Latitude**		**do**	**Time**
Long_name	Latitude (positive N, negative S) (Ku-band) at 1Hz			1
Units	Unit name	Degree		1
Comment	Latitude of measurement [-90, +90]: Positive at North, Negative at South			1
Longitude_20Hz	**Longitude**		**do**	**Time**
Long_name	Longitude (positive E, negative W) (Ku-band) at 20 Hz			1
Units	Unit name	Degree		1
Comment	longitude of measurement [-180, +180]: Positive at East, Negative at West			1
Longitude_1Hz	**Longitude**		**do**	**Time**
Long_name	Longitude (positive E, negative W) (Ku-band) at 1 Hz			1
Units	Unit name	Degree		1
Comment	longitude of measurement [-180, +180]: Positive at East, Negative at West			1
Altitude_20Hz	**Altitude**		**do**	**Time**
Long_name	Altitude of satellite at 20 Hz			1
Units	Unit name	Meters		1
Comment	Altitude of the satellite Centre of Mass			1
Altitude_1Hz	**Altitude**		**do**	**Time**
Long_name	Altitude of satellite at 1 Hz			1
Units	Unit name	Meters		1
Comment	Altitude of the satellite Centre of Mass			1
Altitude_rate_20Hz	**Altitude rate**		**do**	**Time**

Long_name	Orbital altitude rate at 20 Hz			1
Units	Unit name	m/s		1
Comment	Instantaneous altitude rate at the Centre of Mass			1
Altitude_rate_1Hz	**Altitude rate**		**do**	**Time**
Long_name	Orbital altitude rate at 1 Hz			1
Units	Unit name	m/s		1
Comment	Instantaneous altitude rate at the Centre of Mass			1
Roll_20Hz			**do**	**Time**
Long_name	Mispointing angle, measured by STRs at 20 Hz			1
Units	Unit name	degrees		1
Comment	Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility			1
Roll_1Hz			**do**	**Time**
Long_name	Mispointing angle, measured by STRs at 1 Hz			1
Units	Unit name	degrees		1
Comment	Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility			1
Pitch_20Hz			**do**	**Time**
Long_name	Mispointing angle, measured by STRs at 20 Hz			1
Units	Unit name	degrees		1
Comment	Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility			1
Pitch_1Hz			**do**	**Time**
Long_name	Mispointing angle, measured by STRs at 1 Hz			1
Units	Unit name	degrees		1
Comment	Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility			1
Velocity				

x_vel_20Hz	**Satellite velocity x component**		**s**	**Time**
Long_name	Satellite velocity-x component at 20 Hz			1
Units	Unit name	m/s		1
x_vel_1Hz	**Satellite velocity x component**		**s**	**Time**
Long_name	Satellite velocity-x component at 1 Hz			1
Units	Unit name	m/s		1
y_vel_20Hz	**Satellite velocity y component**		**s**	**Time**
Long_name	Satellite velocity-y component at 20 Hz			1
Units	Unit name	m/s		1
y_vel_1Hz	**Satellite velocity y component**		**s**	**Time**
Long_name	Satellite velocity-y component at 1 Hz			1
Units	Unit name	m/s		1
z_vel_20Hz	**Satellite velocity z component**		**s**	**Time**
Long_name	Satellite velocity-z component at 20 Hz			1
Units	Unit name	m/s		1
z_vel_1Hz	**Satellite velocity z component**		**s**	**Time**
Long_name	Satellite velocity-z component at 1 Hz			1
Units	Unit name	m/s		1
COR2, and AGC				
Ho_20Hz	**Ho**		**s**	**Time**
Long_name	Applied altitude command HO at 20 Hz			1
Units	Unit name	3.125/64*1e-9 second		1
Comment	Value the closest in time to the reference measurement			1
Ho_1Hz	**Ho**		**s**	**Time**
Long_name	Applied altitude command HO at 1 Hz			1

Units	Unit name	3.125/64*1e-9 second		1
Comment	Value the closest in time to the reference measurement			1
Cor2_20Hz	**COR2**		**s**	**Time**
Long_name	Applied altitude command COR2 at 20 Hz			1
Units	Unit name	3.125/1024*1e-9 second		1
Comment	Value the closest in time to the reference measurement			1
Cor2_1Hz	**COR2**		**s**	**Time**
Long_name	Applied altitude command COR2 at 1 Hz			1
Units	Unit name	3.125/1024*1e-9 second		1
Comment	Value the closest in time to the reference measurement			1
Agc_20Hz	**AGC_code**		**s**	**Time**
Long_name	AGC code for Ku Band at 20 Hz			1
Units	Unit name	dBs		1
Comment	Value the closest in time to the reference measurement			1
Agc_1Hz	**AGC_code**		**s**	**Time**
Long_Name	AGC code for Ku Band at 1 Hz			1
Units	Unit name	dBs		1
Comment	Value the closest in time to the reference measurement			1
Surface Type				
Surf_type	**Surface_type**		**s**	
Long_name	Altimeter surface type			1
Flag_meanings		'Open_ocean or semi-enclosed_seas,		1

		enclosed_seas or lakes, continental_ice, land, Land		
Comment	Value the closest in time to the reference measurement			1
Altimeter Range				
Range_20Hz	**Range**		**do**	
Long_name	Corrected Range for Ku band at 20 Hz			1
Units	Unit name	Meters		1
Comment	One-way distance from the satellite to the surface point, expressed in meters. It includes the USO frequency drift and internal path corrections.			1
Range_1Hz	**Range**		**do**	
Long_name	Corrected Range for Ku band at 1 Hz			1
Units	Unit name	Meters		1
Comment	One-way distance from the satellite to the surface point, expressed in meters. It includes the USO frequency drift and internal path corrections.			1
Range_rate_20Hz	**Range_rate**		**do**	
Long_name	Range rate at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Range_rate_1Hz	**Range_rate**		**do**	
Long_name	Range rate at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Uso_20Hz	**Uso_cor**		**do**	
Long_name	USO frequency drift correction at 20 Hz			1
Units	Unit name	Meters		1

Comment	Value the closest in time to the reference measurement			1
Uso_1Hz	**Uso_cor**		**do**	
Long_name	USO frequency drift correction at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Int_path_20Hz	**Int_path_cor**		**do**	
Long_name	Internal path correction for Ku band at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Int_path_1Hz	**Int_path_cor**		**do**	
Long_name	Internal path correction for Ku band at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Sigma0 scaling				
Waveform_scale_20Hz	**Waveform_scale**		**do**	
Long_name	Echo scale factor, to convert from [0-65535 to power at antenna flange at 20 Hz			1
Units	Unit name	Watt		1
Comment	The L1B waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B waveform into Watts is applied as follows: power_waveform_watt(ku_rec, Ns) = i2q2_meas_ku_l1b_echo_sar_ku(ku_rec, Ns) * (waveform_scale_factor_l1b_echo_sar_ku(ku_rec)			1
Waveform_scale_1Hz	**Waveform_scale**		**do**	
Long_name	Echo scale factor, to convert from [0-65535 to power at antenna flange at 1 Hz			1
Units	Unit name	Watt		1

Comment	The L1B waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B waveform into Watts is applied as follows: power_waveform_watt(ku_rec, Ns) = i2q2_meas_ku_l1b_echo_sar_ku(ku_rec, Ns) * (waveform_scale_factor_l1b_echo_sar_ku(ku_rec)			1
Scale_factor_sigma_20Hz	**Scale_factor_sigma**		**do**	
Long_name	Scaling factor for sigma0 evaluation at 20Hz			1
Units	Unit name	dBs		1
Comment	This is a scaling factor in order to retrieve sigma-0 from the L1B waveform. It includes antenna gains and geometry satellite - surface. It is not applied to the L1B waveforms			1
Scale_factor_sigma_1Hz	**Scale_factor_sigma**		**do**	
Long_name	Scaling factor for sigma0 evaluation at 1Hz			1
Units	Unit name	dBs		1
Comment	'This is a scaling factor in order to retrieve sigma-0 from the L1B waveform. It includes antenna gains and geometry satellite - surface. It is not applied to the L1B waveforms			1
Geophysical Corrections				
Dry_tropo_20Hz	**Dry_tropo_corr**		**do**	
Long_name	Dry Tropospheric Correction at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Dry_tropo_1Hz	**Dry_tropo_corr**		**do**	
Long_name	Dry Tropospheric Correction at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Wet_tropo_20Hz	**Wet_tropo_corr**		**do**	
Long_name	Wet Tropospheric Correction at 20 Hz			1

Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Wet_tropo_1Hz	**Wet_tropo_corr**		**do**	
Long_name	Wet Tropospheric Correction at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Inv_baro_20Hz	**Inv_baro_corr**		**do**	
Long_name	Inverse Barometric Correction at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Inv_baro_1Hz	**Inv_baro_corr**		**do**	
Long_name	Inverse Barometric Correction at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
GIM_iono_20Hz	**GIM_iono_corr**		**do**	
Long_name	GIM Ionospheric Correction at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
GIM_iono_1Hz	**GIM_iono_corr**		**do**	
Long_name	GIM Ionospheric Correction at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Mod_iono_20Hz	**Mod_iono_corr**		**do**	

Long_name	Model Ionospheric Correction at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Mod_iono_1Hz	**Mod_iono_corr**		**do**	
Long_name	Model Ionospheric Correction at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Oc_eq_tide_20Hz	**Ocean:equ_tide**		**do**	
Long_name	Ocean Equilibrium Tide at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Oc_eq_tide_1Hz	**Ocean:equ_tide**		**do**	
Long_name	Ocean Equilibrium Tide at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Long_tide_20Hz	**Long_Period_Oc_tide**		**do**	
Long_name	Long Period Ocean Tide at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Long_tide_1Hz	**Long_Period_Oc_tide**		**do**	
Long_name	Long Period Ocean Tide at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1

Oc_load_tide_20Hz	**Ocean_load_tide**		**do**	
Long_name	Ocean Loading Tide at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Oc_load_tide_1Hz	**Ocean_load_tide**		**do**	
Long_name	Ocean Loading Tide at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Sol_earth_tide_20Hz	**Solid_earth_tide**		**do**	
Long_name	Solid_earth_tide at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Sol_earth_tide_1Hz	**Solid_earth_tide**		**do**	
Long_name	Solid_earth_tide at 1 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Geo_polar_tide _20Hz	**Geocentric_polar_tide**		**do**	
Long_name	Geocentric Polar Tide at 20 Hz			1
Units	Unit name	Meters		1
Comment	Value the closest in time to the reference measurement			1
Geo_polar_tide _1Hz	**Geocentric_polar_tide**		**do**	
Long_name	Geocentric Polar Tide at 1 Hz			1
Units	Unit name	Meters		1

Comment	Value the closest in time to the reference measurement			1
Number of Waveforms				
Nb_stack				
Long_name	Number of waveforms summed in stack (contributing beams: effective number of looks or beams from stack used in multi-looking; if beams with all samples set to zero not to be included in multi-looking they are accordingly not accounted in this number; if there are some gaps in-between mask set to zero all the samples related to those beams and they will not be contributing to the multi-looking.			
Units	Unit name	Counts		
Nb_stack_start				
Long_name	Number of waveforms summed in stack (considering the number of beams/looks from start and stop beams: they correspond to the first and last beams at edges of stack. If option of discarding beams with all-zeros samples these corresponds to the first and last beams with non-all zeros samples (if there exists gaps in between: mask setting to zero all samples. these in between beams are considered anyway in the "nb_stack_start_stop_l1b_echo_sar_ku"), otherwise they correspond to the very first and very last beam in the stack) This number of beams will be useful to construct accordingly the modelled stack for re-tracking.			
Units	Unit name	Counts		
Retracker Outputs				
epoch_20Hz	**epoch**		**s**	
Long_name	Epoch at 20 Hz			
Units	Unit name	Counts		1
Comment	Point over the echo trailing edge related to the tracking point.			1
epoch_1Hz	**epoch**		**s**	
Long_name	Epoch at 1 Hz			

Units	Unit name	Counts		1
Comment	Point over the echo trailing edge related to the tracking point.			1
ssh_20Hz	**SSH non corrected**		**s**	
Long_name	Sea Surface Height in SAR mode (ocean re-tracking) at 20 Hz			
Units	Unit name	Meters		1
Comment	No corrections applied to the measurement			1
ssh_1Hz	**SSH non corrected**		**s**	
Long_name	Sea Surface Height in SAR mode (ocean re-tracking) at 1 Hz			
Units	Unit name	Meters		1
Comment	No corrections applied to the measurement			1
ssh_corr_20Hz	**SSH corrected**		**s**	
Long_name	Sea Surface Height in SAR mode (ocean re-tracking) at 20 Hz after applying atmospheric and tides corrections			1
Units	Unit name	Meters		1
Comment	Sea Surface Height in SAR mode (ocean retracking) with corrections (i.e. tides (ocean tide, long period eq, ocean loading tide, solid earth tide, and geocentric polar tide), and atmosphere (dry tropospheric, wet tropospheric, ionospheric, and dynamic atmospheric))			1
ssh_corr_1Hz	**SSH corrected**		**s**	
Long_name	Sea Surface Height in SAR mode (ocean re-tracking) at 1 Hz after applying atmospheric and tides corrections			1
Units	Unit name	Meters		1
Comment	Sea Surface Height in SAR mode (ocean retracking) with corrections (i.e. tides (ocean tide, long period eq, ocean loading tide, solid earth tide, and geocentric polar tide), and atmosphere (dry tropospheric, wet tropospheric, ionospheric, and dynamic atmospheric))			1

swh_20Hz	**SWH**		**s**	
Long_name	Significant Wave Height in SAR mode (ocean re-tracking)			1
Units	Unit name	Meters		1
swh_1Hz	**SWH**		**s**	
Long_name	Significant Wave Height in SAR mode (ocean re-tracking)			1
Units	Unit name	Meters		1
Pu_20Hz	**Pu**		**s**	
Long_name	Amplitude ocean re-tracking (FFT power unit) at 20 Hz			1
Units	Unit name	Counts		1
Comment	Pu is meant to be a measurement of the received signal power, from Calibrated and Multilooked L1b SAR Power Waveforms			
Pu_1Hz	**Pu**		**s**	
Long_name	Amplitude ocean re-tracking (FFT power unit) at 1 Hz			1
Units	Unit name	Counts		1
Comment	Pu is meant to be a measurement of the received signal power, from Calibrated and Multilooked L1b SAR Power Waveforms			
Sigma0_20Hz	**Sigma0**			
Long_name	Sigma0 at 20 Hz			1
Units	Unit name	dB		1
Comment	Sigma0 computed from the Pu, accounting for the antenna gains and geometry satellite-surface parameters			1
Sigma0_1Hz	**Sigma0**			
Long_name	Sigma0 at 1 Hz			1
Units	Unit name	dB		1

Comment	Sigma0 computed from the Pu, accounting for the antenna gains and geometry satellite-surface parameters			1
Misfit_20Hz	**MISFIT**		**s**	
Long_name	MISFIT at 20Hz			1
Units	Unit name	-		1
Comment	Quality of the fit between the L1B waveform and the fitted model			1
Misfit_1Hz	**MISFIT**		**s**	
Long_name	MISFIT at 1Hz			1
Units	Unit name	-		1
Comment	Quality of the fit between the L1B waveform and the fitted model			1

Epoch, Pu, and swh, are the parameters estimated from the re-tracker.

The ssh is computed as the difference between the satellite altitude and the range measurement, as

$$ssh = altitude - range\_meas \qquad (1)$$

where altitude is the satellite altitude (see Table 4.1). The range_meas is computed as,

$$range\_meas = (range + retrac\_corr) \qquad (2)$$

where Range is provided as an input (see Table 4.1), and retrac_corr is the difference between the tracking point (epoch in Table 4.1), and a reference point for the measurement of range to surface. Thus, retrac_corr. Is given by,

$$\text{retrac\_corr} = (epoch - Ns/2).* dR, \qquad (3)$$

where Ns is equal to the number of lags in the waveform (128 in this case), and dR, is the range between consecutive gates (i.e. $dR = c/f_s$=0.4688). Therefore, Eqn. 1 becomes,

$$ssh = altitude - (range + (epoch - 64).* 0.4688) \qquad (4)$$

And the equivalent after applying corrections as,

$$ssh_{corr} = altitude - (range + (epoch - 64).* 0.4688 + corr_f), \qquad (5)$$

Where corr_f are the corrections applied, which for the ocean case is given by,

$$corr\_f = dry\_tropo + wet\_tropo + inv\_baro + gim\_iono + dyn\_atm + oc\_eq\_tide + \dots$$
$$+ long\_tide + oc\_load\_tide + sol\_earth\_tide + geo\_polar\_tide; \qquad (6)$$

where the different atmospheric and tides corrections are detailed in Table 4.1

The sigma0 has been computed based on the expression provided in [RD-07],

$$\sigma_0 = 10.* log10\left(.\frac{Pu}{Tx_{power}}\right) + 10.* log10(K) + offset, \quad (7)$$

As,

$$\sigma_0 = 10.* log10(Pu.* waveform\ scale) + scale\ factor + offset, \quad (8)$$

where, Pu is the Power de-noised estimated from the re-tracker. Waveform scale, is a echo scale used to convert from L1b Waveforms Amplitude [i.e. 0-65535] to Power at antenna [Watts]. Therefore, this parameter is used to convert the *SAR waveform* provided in the L1b file to Watts. Scale factor, is a scaling factor used to compute the sigma0. This parameter includes the antenna gains and geometry satellite-surface parameters, and offset, is an offset parameter used to scale the sigma0.

Finally, Misfit (which represents the quality of the fit between the L1b waveform and the simulated one), is calculated as the root mean square of sum of the residuals scaled by the number of bins in the waveform.

$$misfit = 100 * \sqrt{\frac{1}{N}\sum_{0}^{N-1}(residual^2)}, \quad (9)$$

where residuals are

$$residual = \frac{(model - data(bin_i : bin_n))}{\max(data(bin_i : bin_n))} \quad (10)$$

and *model* represents the waveform obtained by the SAMOSA retracker, and *data* the real waveform.

4.5 NetCDF format file

NetCDF is the format selected for the Sentinel-3 L1A, L1B, and L2 data products, based on its characteristics (is self-describing, portable, flexible, and is considered a standard).

Below we give an example of a generated L2 file.

'CR2_SR_2_SRA____20121001T112405_20121001T112846_20160724T210218_stl.nc'

Source:

D:\SCOOP\NEW_SENTINEL_3_data_corr\LATEST\LATEST_II\West_Pacific\2012\CR2_SR_2_SRA____20121001T112405_20121001T112846_20160724T210218_stl.nc

Format:

classic

Dimensions:

time = 6316

time_1Hz = 315

Variables:

Time_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'UTC Seconds since 2000-01-01 00:00:00.0+00:00 (Ku-band) at 20 Hz'

calendar = 'Gregorian'

units = 'seconds'

comment = 'time at surface of the SAR measurement(multilooked waveform)'

Day

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Days since 2000-01-01 00:00:00.0+00:00 (Ku-band)'

units = 'days'

comment = 'days elapsed since 2000-01-01. To be used to link with L1 and L2 records (time_l1b provides the number of seconds since 2000-01-01)'

Sec

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Seconds in the day UTC, with microsecond resolution (Ku-band)'

units = 'seconds'

comment = 'seconds in the day. To be used to link L1 and L2 records'

Latitude_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Latitude (positive N, negative S) (Ku-band) at 20 Hz'

units = 'degrees'

comment = 'Latitude of measurement [-90, +90]: Positive at Nord, Negative at South'

Longitude_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Longitude (positive E, negative W) (Ku-band) at 20 Hz'

units = 'degrees'

comment = 'Longitude of measurement [-180, +180]: Positive at East, Negative at West'

Altitude_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Altitude of satellite at 20 Hz'

units = 'meters'

comment = 'Altitude of the satellite Centre of Mass'

Altitude_rate_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Orbital altitude rate at 20 Hz'

units = 'm/s'

comment = 'Instantaneous altitude rate at the Centre of Mass'

x_pos_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Satellite altitude-x component at 20 Hz'

units = 'meters'

y_pos_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Satellite altitude-y component at 20 Hz'

units = 'meters'

z_pos_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Satellite altitude-z component at 20 Hz'

units = 'meters'

x_vel_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Satellite velocity-x component at 20 Hz'

units = 'm/s'

y_vel_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Satellite velocity-y component at 20 Hz'

units = 'm/s'

z_vel_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Satellite velocity-z component at 20 Hz'

units = 'm/s'

roll_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Mispointing roll angle, measured by STRs at 20 Hz'

units = 'degrees'

comment = 'Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility' pitch_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Mispointing pitch angle, measured by STRs at 20 Hz'

units = 'degrees'

comment = 'Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility'

Ho_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Applied altitude command H0 at 20 Hz'

units = '3.125/64*1e-9 seconds'

comment = 'Value the closest in time to the reference measurement'

Cor2_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Applied altitude command COR2 at 20 Hz'

units = '3.125/64*1e-9 seconds'

comment = 'Value the closest in time to the reference measurement'

Agc_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'AGCCODE for Ku band at 20 Hz'

units = 'dB'

comment = 'Value the closest in time to the reference measurement'

Surf_type

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Altimeter surface type'

flag_values = '0, 1, 2, 3'

flag_meanings = 'Open_ocean or semi-enclosed_seas, enclosed_seas or lakes, continental_ice, land,Transponder'

comment = 'Value the closest in time to the reference measurement'

Range_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Corrected range for Ku band at 20 Hz'

units = 'meters'

comment = 'One-way distance from the satellite to the surface point, expressed in meters. It includes the USO frequency drift and internal path corrections.'

Range_rate_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Range rate at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Uso_cor_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'USO frequency drift correction at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Int_path_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Internal path correction for Ku band at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Waveform_scale_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Echo Scale Factor, to convert from [0-65535] to Power at antenna flange at 20 Hz'

units = 'Watt/#'

comment = 'The L1B waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B waveform into Watt, is applied as follows: power_waveform_watt(ku_rec, Ns) = i2q2_meas_ku_l1b_echo_sar_ku(ku_rec, Ns) * waveform_scale_factor_l1b_echo_sar_ku(ku_rec)'

Scale_factor_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Scaling factor for sigma0 evaluation at 20 Hz'

units = 'dB'

comment = 'This is a scaling factor in order to retrieve sigma-0 from the L1B waveform. It includes antenna gains and geometry satellite - surface. It is not applied to the L1B waveforms'

Nb_stack

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Number of waveforms summed in stack (contributing beams: effective number of looks or beams from stack used in multilooking; if beams with all samples set to zero not to be included in multilooking they are accordingly not accounted in this number; if there are some gaps in-between mask set to zero all the samples related to those beams and they will not be contributing to the multilooking)'

units = 'counts'

Nb_stack_start

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Number of waveforms in stack (considering the number of beams/looks from start and stop beams: they correspond to the first and last beams at edges of stack. If option of discarding beams with all-zeros samples these correspond to the first and last beams with non-all zeros samples (if there exist gaps in between: mask setting to zero all samples, these in-between beams are considered anyway in the "nb_stack_start_stop_l1b_echo_sar_ku"), otherwise they correspond to the very first and very last beam in the stack). This number of beams will be useful to construct accordingly the modelled stack for retracking'

units = 'counts'

Dry_tropo_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Dry Tropospheric Correction at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Wet_tropo_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Wet Tropospheric correction at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Inv_baro_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Inverse Barometric Correction at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

GIM_iono_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'GIM Ionospheric Correction at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Dyn_atm_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Dynamic Atmospheric Correction at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Oc_eq_tide_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Ocean Equilibrium Tide at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Long_tide_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Long Period Ocean Tide at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Oc_load_tide_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Ocean Loading Tide at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Sol_earth_tide_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Solid Earth Tide at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Geo_polar_tide_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Geocentric Polar Tide at 20 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Epoch_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Epoch at 20 Hz'

units = 'counts'

comment = 'Point over the echo leading edge, used to mark the poin of measurement of range to surface'

ssh_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Sea Surface Height'

units = 'meters'

comment = 'Sea Surface Height in SAR mode (ocean retracking) without corrections'

ssh_corr_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Sea Surface Height with corrections at 20 Hz'

units = 'meters'

comment = 'Sea Surface Height in SAR mode (ocean retracking) with corrections (i.e. tides (ocean tide, long period eq, ocean loading tide, solid earth tide, and geocentric polar tide), and atmosphere (dry tropospheric, wet tropospheric, ionospheric, and dynamic atmospheric))'

swh_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Significant Wave Height at 20 Hz'

units = 'meters'

comment = 'Significant Wave Height in SAR mode (ocean retracking)'

pu_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Amplitude ocean retracking (FFT power unit) at 20 Hz'

units = 'counts'

comment = 'Pu is meant to be a measurement of the received signal power, from Calibrated and Multilooked L1b SAR Power Waveforms'

sigma0_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'Sigma0 at 20 Hz'

units = 'dBs'

comment = 'Sigma0 is computed from Pu, using the agc, scale factor, and waveform scale factor provided in the L1b file'

misfit_20Hz

Size: 6316x1

Dimensions: time

Datatype: double

Attributes:

long name = 'MISFIT at 20 Hz'

units = '-'

comment = 'Quality of the fit between the L1B waveform and the fitted model'

Time_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'UTC Seconds since 2000-01-01 00:00:00.0+00:00 (Ku-band) at 1 Hz'

calendar = 'Gregorian'

units = 'seconds'

comment = 'time at surface of the SAR measurement(multilooked waveform)'

Latitude_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Latitude (positive N, negative S) (Ku-band) at 1 Hz'

units = 'degrees'

Longitude_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Longitude (positive E, negative W) (Ku-band) at 1 Hz'

units = 'degrees'

Altitude_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Altitude of satellite at 1 Hz'

units = 'meters'

comment = 'Altitude of the satellite Centre of Mass'

Altitude_rate_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Orbital altitude rate at 1 Hz'

units = 'm/s'

comment = 'Instantaneous altitude rate at the Centre of Mass'

x_pos_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Satellite altitude-x component at 1 Hz'

units = 'meters'

y_pos_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Satellite altitude-y component at 1 Hz'

units = 'meters'

z_pos_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Satellite altitude-z component at 1 Hz'

units = 'meters'

x_vel_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Satellite velocity-x component at 1 Hz'

units = 'm/s'

y_vel_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Satellite velocity-y component at 1 Hz'

units = 'm/s'

z_vel_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Satellite velocity-z component at 1 Hz'

units = 'm/s'

roll_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Mispointing roll angle, measured by STRs at 1 Hz'

units = 'degrees'

comment = 'Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility'

pitch_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Mispointing pitch angle, measured by STRs at 1 Hz'

units = 'degrees'

comment = 'Attitude mispointing, measured by STRs and post-processed by AOCS or by ground facility'

Ho_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Applied altitude command H0 at 1 Hz'

units = '3.125/64*1e-9 seconds'

comment = 'Value the closest in time to the reference measurement'

Cor2_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Applied altitude command COR2 at 1 Hz'

units = '3.125/64*1e-9 seconds'

comment = 'Value the closest in time to the reference measurement'

Agc_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'AGC CODE for Ku band at 1 Hz'

units = 'dB'

comment = 'Value the closest in time to the reference measurement'

Range_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Corrected range for Ku band at 1 Hz'

units = 'meters'

comment = 'One-way distance from the satellite to the surface point, expressed in meters. It includes the USO frequency drift and internal path corrections.'

Range_rate_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Range rate at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Uso_cor_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'USO frequency drift correction at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Int_path_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Internal path correction for Ku band at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Waveform_scale_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Echo Scale Factor, to convert from [0-65535] to Power at antenna flange at 1 Hz'

units = 'Watt/#'

comment = 'The L1B waveform scaling factor, computed in order to best fit each waveform within 2 bytes. The scaling, needed to convert the L1B waveform into Watt, is applied as follows: power_waveform_watt(ku_rec, Ns) = i2q2_meas_ku_l1b_echo_sar_ku(ku_rec, Ns) * waveform_scale_factor_l1b_echo_sar_ku(ku_rec)'

Scale_factor_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Scaling factor for sigma0 evaluation at 1 Hz'

units = 'dB'

comment = 'This is a scaling factor in order to retrieve sigma-0 from the L1B waveform. It includes antenna gains and geometry satellite - surface. It is not applied to the L1B waveforms'

Dry_tropo_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Dry Tropospheric Correction at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Wet_tropo_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Wet Tropospheric correction at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Inv_baro_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Inverse Barometric Correction at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

GIM_iono_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'GIM Ionospheric Correction at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Dyn_atm_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Dynamic Atmospheric Correction at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Oc_eq_tide_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Ocean Equilibrium Tide at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Long_tide_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Long Period Ocean Tide at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Oc_load_tide_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Ocean Loading Tide at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Sol_earth_tide_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Solid Earth Tide at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Geo_polar_tide_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Geocentric Polar Tide at 1 Hz'

units = 'meters'

comment = 'Value the closest in time to the reference measurement'

Epoch_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Epoch at 1 Hz'

units = 'counts'

comment = 'Point over the echo leading edge, used to mark the poin of measurement of range to surface'

ssh_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Sea Surface Height at 1 Hz'

units = 'meters'

comment = 'Sea Surface Height in SAR mode (ocean retracking) without corrections'

ssh_corr_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Sea Surface Height with corrections at 1 Hz'

units = 'meters'

comment = 'Sea Surface Height in SAR mode (ocean retracking) with corrections (i.e. tides (ocean tide, long period eq, ocean loading tide, solid earth tide, and geocentric polar tide), and atmosphere(dry tropospheric, wet tropospheric, ionospheric, and dynamic atmospheric))'

swh_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Significant Wave Height at 1 Hz'

units = 'meters'

comment = 'Significant Wave Height in SAR mode (ocean retracking)'

pu_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Amplitude ocean retracking (FFT power unit) at 1 Hz'

units = 'counts'

comment = 'Pu is meant to be a measurement of the received signal power, from Calibrated and Multilooked L1b SAR Power Waveforms'

sigma0_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'Sigma0 at 1 Hz'

units = 'dBs'

comment = 'Sigma0 is computed from Pu, using the agc, scale factor, and waveform scale factor provided in the L1b file'

misfit_1Hz

Size: 315x1

Dimensions: time_1Hz

Datatype: double

Attributes:

long name = 'MISFIT at 1 Hz'

units = '-'

comment = 'Quality of the fit between the L1B waveform and the fitted model'

5 RDSAR Product Specification

For an overview of the RDSAR processing the reader is referred to [AD. 2], the Algorithm Theoretical Baseline Document (ATBD), and for the input and output to [AD. 4], the Input Output Definitions Document (IODD). In this chapter we describe the RDSAR product's definitions and formats, and the variables. As the final RDSAR product is a product that adheres to RADS definitions we advise for reference to also consult the RADS user and data manuals [RD- 8] and [RD- 9] for a very detailed description on the variables and the RADS data format.

5.1 Product definitions and formats

The RDSAR product comes in two flavours, an intermediate product that already contains the final geophysical parameters (sea level, wave height, and wind speed) and the waveforms that form the basis for these parameters. In that respect it is actually a combined level 1B and level 2 product. This processing step is done with 1 program called `cs2_fbr_to_l1r`. The input for that program is a CryoSat-2 DBL file, level 1A (sometimes referred to as FBR). A description can be found in Section 5.2 of the IODD [AD. 4]. The output file of that program is by RADS convention called an l1r file and gets exactly the same name as the input file but with nc as extension. This refers to the fact that the output product is in netcdf format:

```
CS_LTA__SIR_SAJ_1B_yyyymmddThhmmss_yyyymmddThhmmss_C001.nc
```

with yyyy is year, mm is month, dd is day, hh is hour, the 2nd mm is minute, and ss is second. The C001 indicates that the input product is a Baseline-C product. As indicated the format of the output file is netcdf, so an indication of the product content can be queried by the command `ncdump`. In the next section an `ncdump` output example of an l1r file is given. Table 5-2 in the IODD [AD. 4] presents the variables in table format.

In the next processing step the l1r file is converted to an official RADS data file, which is also in netcdf format. The program for that is called `rads_gen_c2_l1r`. The most important feature of this step is putting the data in pass/cycle files, which is the format of the RADS data base. Normally a cycle is a collection of data (orbits) which are repeated after a certain time. And a pass is data from the most southern point of an orbit to the most northern point of an orbit (so a pass is half an orbit and runs from pole to pole, either from south to north (ascending) or from north to south (descending)). Archiving the data like this facilitates easy crossover analyses between satellites and also collinear pass analyses. For CryoSat-2 a subcycle is chosen otherwise there would be too many passes in a repeat (here 369 days). In the RADS cycle definition (which by the way is identical to the definition by CNES) we have the following sequence of revolutions: 4 * (29 + 29 + 27) + 29 = 369 days, where the 29-day and 27-day are the sub-cycles. In subsequent RADS processing steps (for which the reader is referred to the IODD document [AD. 4], a number of updated models and corrections are applied, for instance fixing a bias in the sigma0 (3.04 dB), adding an SSB (sea state bias) correction, adding newer tide and mean sea surface models, and adding an improved orbital height. All these 'add-ons' get listed automatically in the global attribute 'history' of the output file.

As mentioned, the final output file is in netcdf format:

```
c2/a/c###/c2p####c###.nc
```

with c2 the 2-letter code for CryoSat-2, c### the cycle number (*e.g.* c049), and p#### the pass number (*e.g.* p0102). The data is thus stored under a directory called c2, under a directory called 'a' which indicates the mission (phase) of a satellite (whenever the ground tracks / orbit / repeat of a satellite mission is changed, for instance going from an oceanography mission to a geodetic mission, this letter is changed), and under a directory with cycle number. As indicated the format of the final output file is also netcdf, so an indication of product content can be queried again by the command `ncdump`. In Section 5.3 an `ncdump` output example of a SCOOP processed CryoSat-2 RADS data file is given. Table 5-3 in the IODD [AD. 4] presents the variables of the final RADS RDSAR product in table format. Not every variable will be found back in the different SCOOP products for various reasons. This is indicated in the IODD [AD. 4] and can be summarized as follows:

- **`off_nadir_angle2_wf_ku`**
  Data item only available in MLE4 products (off-nadir pointing is estimated in the MLE4 process)
- **`off_nadir_angle2_wf_rms_ku`**
  Data item only available in MLE4 products (off-nadir pointing is estimated in the MLE4 process)
- **`dsig0_atmos_ku`**
  Data item only available in MLE4 products (correction to sigma0, based on MLE4 estimated off-nadir pointing)
- **`water_vapor_content_gfs`**
  Data item not SCOOP RDSAR specific: recently added as part of RADS 'common' auxiliary info: source NOAA GFS system
- **`liquid_water_gfs`**
  Data item not SCOOP RDSAR specific: recently added as part of RADS 'common' auxiliary info: source NOAA GFS system
- **`tide_ocean_webtide`**
  Data item not SCOOP RDSAR specific: recently added as part of RADS 'common' auxiliary info: source Bedford Institute of Oceanography
- **`wet_tropo_uporto`**
  Data item available when the command "rads_add_uporto –sat c2/a -all" has been executed; it is only readily available in later SCOOP RDSAR products (when it became available). It is also not used as default correction in the SLA calculations. The UPorto wet tropospheric correction though is available as a separate SCOOP data set and can be applied "offline" if not in the RDSAR netcdf.

5.2 RDSAR interim product variables

The netcdf variables in the intermediate `l1r` output file follow from an `ncdump` with the `-h` option (only header information):

```
ncdump -h CS_LTA__SIR_SAJ_1B_20131231T214551_20131231T214713_C001.nc
```

```
netcdf CS_LTA__SIR_SAJ_1B_20131231T214551_20131231T214713_C001 {
dimensions:
     time = 86 ;
     meas_ind = 20 ;
     wf_ind = 256 ;
variables:
     double time_20hz(time, meas_ind) ;
          time_20hz:long_name = "time" ;
```

```
        time_20hz:units = "seconds since 2000-01-01" ;
    int lat_20hz(time, meas_ind) ;
        lat_20hz:long_name = "latitude" ;
        lat_20hz:units = "degrees_north" ;
        lat_20hz:scale_factor = 1.e-07 ;
    int lon_20hz(time, meas_ind) ;
        lon_20hz:long_name = "longitude" ;
        lon_20hz:units = "degrees_east" ;
        lon_20hz:scale_factor = 1.e-07 ;
    int alt_20hz(time, meas_ind) ;
        alt_20hz:long_name = "orbital altitude" ;
        alt_20hz:units = "m" ;
        alt_20hz:scale_factor = 0.001 ;
    int alt_rate_20hz(time, meas_ind) ;
        alt_rate_20hz:long_name = "orbital altitude rate" ;
        alt_rate_20hz:units = "m/s" ;
        alt_rate_20hz:scale_factor = 0.001 ;
    short doppler_corr_20hz(time, meas_ind) ;
        doppler_corr_20hz:long_name = "Doppler correction" ;
        doppler_corr_20hz:units = "m" ;
        doppler_corr_20hz:scale_factor = 0.001 ;
    int uso_corr_20hz(time, meas_ind) ;
        uso_corr_20hz:long_name = "USO correction factor" ;
        uso_corr_20hz:units = "count" ;
        uso_corr_20hz:scale_factor = 1.e-15 ;
    int instr_config_flags_20hz(time, meas_ind) ;
        instr_config_flags_20hz:long_name = "Instrument configuration flags" ;
        instr_config_flags_20hz:units = "count" ;
    int fbr_mcd_20hz(time, meas_ind) ;
        fbr_mcd_20hz:long_name = "FBR measurement confidence data" ;
        fbr_mcd_20hz:units = "count" ;
    short attitude_pitch_20hz(time, meas_ind) ;
        attitude_pitch_20hz:long_name = "attitude pitch" ;
        attitude_pitch_20hz:units = "radians" ;
        attitude_pitch_20hz:scale_factor = 1.e-06 ;
    short attitude_roll_20hz(time, meas_ind) ;
        attitude_roll_20hz:long_name = "attitude roll" ;
        attitude_roll_20hz:units = "radians" ;
        attitude_roll_20hz:scale_factor = 1.e-06 ;
    short attitude_yaw_20hz(time, meas_ind) ;
        attitude_yaw_20hz:long_name = "attitude yaw" ;
        attitude_yaw_20hz:units = "radians" ;
        attitude_yaw_20hz:scale_factor = 1.e-06 ;
    int instr_range_corr_20hz(time, meas_ind) ;
        instr_range_corr_20hz:long_name = "instrument correction to range" ;
        instr_range_corr_20hz:units = "m" ;
        instr_range_corr_20hz:scale_factor = 0.001 ;
    int range_20hz(time, meas_ind) ;
        range_20hz:long_name = "tracker range" ;
        range_20hz:units = "m" ;
        range_20hz:scale_factor = 0.001 ;
    short drange_20hz(time, meas_ind) ;
        drange_20hz:long_name = "retracker range correction" ;
        drange_20hz:units = "m" ;
        drange_20hz:scale_factor = 0.001 ;
    short swh_20hz(time, meas_ind) ;
        swh_20hz:long_name = "significant wave height" ;
```

```
        swh_20hz:units = "m" ;
        swh_20hz:scale_factor = 0.001 ;
    short xi_sq_20hz(time, meas_ind) ;
        xi_sq_20hz:long_name = "off-nadir angle squared" ;
        xi_sq_20hz:units = "degrees^2" ;
        xi_sq_20hz:scale_factor = 0.0001 ;
    int noise_20hz(time, meas_ind) ;
        noise_20hz:long_name = "pre-arrival noise" ;
        noise_20hz:units = "dB" ;
        noise_20hz:scale_factor = 0.001 ;
    int echo_scale_20hz(time, meas_ind) ;
        echo_scale_20hz:long_name = "echo scale factor" ;
        echo_scale_20hz:units = "dB" ;
        echo_scale_20hz:scale_factor = 0.001 ;
    short agc_20hz(time, meas_ind) ;
        agc_20hz:long_name = "automatic gain control" ;
        agc_20hz:units = "dB" ;
        agc_20hz:scale_factor = 0.01 ;
    short dagc_eta_20hz(time, meas_ind) ;
        dagc_eta_20hz:long_name = "flat earth correction to backscatter" ;
        dagc_eta_20hz:units = "dB" ;
        dagc_eta_20hz:scale_factor = 0.001 ;
    short dagc_alt_20hz(time, meas_ind) ;
        dagc_alt_20hz:long_name = "altitude correction to backscatter" ;
        dagc_alt_20hz:units = "dB" ;
        dagc_alt_20hz:scale_factor = 0.001 ;
    short dagc_xi_20hz(time, meas_ind) ;
        dagc_xi_20hz:long_name = "off-nadir angle correction to backscatter" ;
        dagc_xi_20hz:units = "dB" ;
        dagc_xi_20hz:scale_factor = 0.001 ;
    short dagc_swh_20hz(time, meas_ind) ;
        dagc_swh_20hz:long_name = "significant wave height correction to
backscatter" ;
        dagc_swh_20hz:units = "dB" ;
        dagc_swh_20hz:scale_factor = 0.001 ;
    int agc_amp_20hz(time, meas_ind) ;
        agc_amp_20hz:long_name = "retracker backscatter" ;
        agc_amp_20hz:units = "dB" ;
        agc_amp_20hz:scale_factor = 0.001 ;
    float mqe_20hz(time, meas_ind) ;
        mqe_20hz:long_name = "mean square error of retracker fit" ;
        mqe_20hz:units = "count" ;
    short peakiness_20hz(time, meas_ind) ;
        peakiness_20hz:long_name = "waveform peakiness" ;
        peakiness_20hz:units = "count" ;
        peakiness_20hz:scale_factor = 0.01 ;
    byte retrack_flag_20hz(time, meas_ind) ;
        retrack_flag_20hz:long_name = "retracking status flag" ;
        retrack_flag_20hz:units = "count" ;
    byte nr_iter_20hz(time, meas_ind) ;
        nr_iter_20hz:long_name = "number of retracker iterations" ;
        nr_iter_20hz:units = "count" ;
    short nr_echoes_20hz(time, meas_ind) ;
        nr_echoes_20hz:long_name = "number of echoes averaged in waveform" ;
        nr_echoes_20hz:units = "count" ;
    short waveform_flags_20hz(time, meas_ind) ;
        waveform_flags_20hz:long_name = "wave form flags" ;
```

```
        waveform_flags_20hz:units = "count" ;
    double time(time) ;
        time:long_name = "time" ;
        time:units = "seconds since 2000-01-01" ;
    int lat(time) ;
        lat:long_name = "latitude" ;
        lat:units = "degrees_north" ;
        lat:scale_factor = 1.e-07 ;
    int lon(time) ;
        lon:long_name = "longitude" ;
        lon:units = "degrees_east" ;
        lon:scale_factor = 1.e-07 ;
    int alt(time) ;
        alt:long_name = "orbital altitude" ;
        alt:units = "m" ;
        alt:scale_factor = 0.001 ;
    byte nr_valid(time) ;
        nr_valid:long_name = "number of 20-Hz values" ;
        nr_valid:units = "count" ;
    short dry_tropo(time) ;
        dry_tropo:long_name = "dry tropospheric correction" ;
        dry_tropo:units = "m" ;
        dry_tropo:scale_factor = 0.001 ;
    short wet_tropo(time) ;
        wet_tropo:long_name = "wet tropospheric correction" ;
        wet_tropo:units = "m" ;
        wet_tropo:scale_factor = 0.001 ;
    short inv_baro(time) ;
        inv_baro:long_name = "inverse barometer correction" ;
        inv_baro:units = "m" ;
        inv_baro:scale_factor = 0.001 ;
    short dac(time) ;
        dac:long_name = "dynamic atmospheric correction" ;
        dac:units = "m" ;
        dac:scale_factor = 0.001 ;
    short iono_gim(time) ;
        iono_gim:long_name = "GIM ionospheric correction" ;
        iono_gim:units = "m" ;
        iono_gim:scale_factor = 0.001 ;
    short iono_model(time) ;
        iono_model:long_name = "model ionospheric correction" ;
        iono_model:units = "m" ;
        iono_model:scale_factor = 0.001 ;
    short tide_ocean(time) ;
        tide_ocean:long_name = "equilibrium ocean tide" ;
        tide_ocean:units = "m" ;
        tide_ocean:scale_factor = 0.001 ;
    short tide_lp(time) ;
        tide_lp:long_name = "long-period tide" ;
        tide_lp:units = "m" ;
        tide_lp:scale_factor = 0.001 ;
    short tide_load(time) ;
        tide_load:long_name = "loading tide" ;
        tide_load:units = "m" ;
        tide_load:scale_factor = 0.001 ;
    short tide_solid(time) ;
        tide_solid:long_name = "solid earth tide" ;
```

```
        tide_solid:units = "m" ;
        tide_solid:scale_factor = 0.001 ;
    short tide_pole(time) ;
        tide_pole:long_name = "pole tide" ;
        tide_pole:units = "m" ;
        tide_pole:scale_factor = 0.001 ;
    byte surface_type(time) ;
        surface_type:long_name = "surface type" ;
        surface_type:units = "count" ;
    short corr_status_flags(time) ;
        corr_status_flags:long_name = "correction status flags" ;
        corr_status_flags:units = "count" ;
        corr_status_flags:scale_factor = 0.001 ;
    short corr_error_flags(time) ;
        corr_error_flags:long_name = "correction error flags" ;
        corr_error_flags:units = "count" ;
        corr_error_flags:scale_factor = 0.001 ;
    short sig_amp_20hz(time, meas_ind) ;
        sig_amp_20hz:long_name = "formal error of waveform amplitude" ;
        sig_amp_20hz:units = "count" ;
        sig_amp_20hz:scale_factor = 0.1 ;
    short rho_amp_range_20hz(time, meas_ind) ;
        rho_amp_range_20hz:long_name = "correlation between amplitude and range" ;
        rho_amp_range_20hz:units = "count" ;
        rho_amp_range_20hz:scale_factor = 0.0001 ;
    short sig_range_20hz(time, meas_ind) ;
        sig_range_20hz:long_name = "formal error of tracker range" ;
        sig_range_20hz:units = "m" ;
        sig_range_20hz:scale_factor = 0.001 ;
    short rho_amp_swh_20hz(time, meas_ind) ;
        rho_amp_swh_20hz:long_name = "correlation between amplitude and SWH" ;
        rho_amp_swh_20hz:units = "count" ;
        rho_amp_swh_20hz:scale_factor = 0.0001 ;
    short rho_range_swh_20hz(time, meas_ind) ;
        rho_range_swh_20hz:long_name = "correlation between range and SWH" ;
        rho_range_swh_20hz:units = "count" ;
        rho_range_swh_20hz:scale_factor = 0.0001 ;
    short sig_swh_20hz(time, meas_ind) ;
        sig_swh_20hz:long_name = "formal error of significant wave height" ;
        sig_swh_20hz:units = "m" ;
        sig_swh_20hz:scale_factor = 0.001 ;
    short waveform_20hz(time, meas_ind, wf_ind) ;
        waveform_20hz:long_name = "waveform" ;
        waveform_20hz:units = "count" ;
        waveform_20hz:add_offset = 32768. ;

// global attributes:
        :Conventions = "COARDS/CF-1.0" ;
        :title = "CryoSat-2 Level-1 Retracked" ;
        :product = "CS_LTA__SIR_SAJ_1B_20131231T214551_20131231T214713_C001" ;
        :mle_params = 4 ;
        :waveform_avg = 0 ;
        :doris_nav = 0 ;
        :l1r_version = "2.06" ;
        :l1r_proc_time = "2019-01-31 13:42:26" ;
        :l1b_version = "SIR1SAR/4.5    " ;
        :l1b_proc_time = "2015-11-27 03:13:48" ;
```

```
		:equator_time = 441842523.490515 ;
		:equator_longitude = 5.614779 ;
		:start_time = "2013-12-31 21:46:25" ;
		:stop_time = "2013-12-31 21:47:47" ;
		:tai_utc = 35 ;
		:abs_orbit_start = 19785 ;
		:cycle_number = 49, 49 ;
		:pass_number = 102, 102 ;
		:record_number = 86, 0 ;
}
```

5.3 RDSAR final product variables

The netcdf variables in the final RADS RDSAR output file follow from an `ncdump` with the `-h` option (only header information):

```
ncdump -h c2/a/c049/c2p0102c049.nc
```

```
netcdf c2p0102c049 {
dimensions:
     time = 86 ;
     meas_ind = 20 ;
     wvf_ind = 256 ;
variables:
     double time(time) ;
          time:long_name = "time" ;
          time:standard_name = "time" ;
          time:units = "seconds since 1985-01-01 00:00:00 UTC" ;
          time:field = 101s ;
          time:comment = "UTC time of measurement. Attribute leap_second gives time
of leap second if any occurs during the data set" ;
     byte meas_ind(meas_ind) ;
          meas_ind:long_name = "elementary measurement index" ;
          meas_ind:units = "1" ;
          meas_ind:comment = "Added to be CF-compliant" ;
     short wvf_ind(wvf_ind) ;
          wvf_ind:long_name = "waveform index" ;
          wvf_ind:units = "1" ;
          wvf_ind:comment = "Added to be CF-compliant" ;
     double time_20hz(time, meas_ind) ;
          time_20hz:long_name = "20-Hz time" ;
          time_20hz:standard_name = "time" ;
          time_20hz:units = "seconds since 1985-01-01 00:00:00 UTC" ;
          time_20hz:comment = "UTC time of 20-Hz measurement. Attribute leap_second
gives time of leap second if any occurs during the data set" ;
     int lat(time) ;
          lat:_FillValue = 2147483647 ;
          lat:long_name = "latitude" ;
          lat:standard_name = "latitude" ;
          lat:units = "degrees_north" ;
          lat:scale_factor = 1.e-07 ;
          lat:field = 201s ;
          lat:comment = "Positive latitude is North latitude, negative latitude is
South latitude" ;
     int lat_20hz(time, meas_ind) ;
          lat_20hz:_FillValue = 2147483647 ;
          lat_20hz:long_name = "20-Hz latitude" ;
          lat_20hz:standard_name = "latitude" ;
          lat_20hz:units = "degrees_north" ;
          lat_20hz:scale_factor = 1.e-07 ;
          lat_20hz:comment = "Positive latitude is North latitude, negative latitude
is South latitude" ;
     int lon(time) ;
          lon:_FillValue = 2147483647 ;
          lon:long_name = "longitude" ;
          lon:standard_name = "longitude" ;
```

```
            lon:units = "degrees_east" ;
            lon:scale_factor = 1.e-07 ;
            lon:field = 301s ;
            lon:comment = "East longitude relative to Greenwich meridian" ;
      int lon_20hz(time, meas_ind) ;
            lon_20hz:_FillValue = 2147483647 ;
            lon_20hz:long_name = "20-Hz longitude" ;
            lon_20hz:standard_name = "longitude" ;
            lon_20hz:units = "degrees_east" ;
            lon_20hz:scale_factor = 1.e-07 ;
            lon_20hz:comment = "East longitude relative to Greenwich meridian" ;
      short alt_rate(time) ;
            alt_rate:_FillValue = 32767s ;
            alt_rate:long_name = "orbital altitude rate" ;
            alt_rate:units = "m/s" ;
            alt_rate:scale_factor = 0.002 ;
            alt_rate:coordinates = "lon lat" ;
            alt_rate:field = 501s ;
            alt_rate:comment = "The reference surface for the orbital altitude rate is
MSS" ;
      int alt_cnes(time) ;
            alt_cnes:_FillValue = 2147483647 ;
            alt_cnes:long_name = "CNES orbital altitude" ;
            alt_cnes:standard_name = "height_above_reference_ellipsoid" ;
            alt_cnes:source = "CNES" ;
            alt_cnes:units = "m" ;
            alt_cnes:scale_factor = 0.0001 ;
            alt_cnes:add_offset = 700000. ;
            alt_cnes:coordinates = "lon lat" ;
            alt_cnes:field = 404s ;
            alt_cnes:comment = "Altitude of satellite above the TOPEX reference
ellipsoid" ;
      int alt_cnes_20hz(time, meas_ind) ;
            alt_cnes_20hz:_FillValue = 2147483647 ;
            alt_cnes_20hz:long_name = "20-Hz CNES orbital altitude" ;
            alt_cnes_20hz:standard_name = "height_above_reference_ellipsoid" ;
            alt_cnes_20hz:source = "CNES" ;
            alt_cnes_20hz:units = "m" ;
            alt_cnes_20hz:scale_factor = 0.0001 ;
            alt_cnes_20hz:add_offset = 700000. ;
            alt_cnes_20hz:coordinates = "lon lat" ;
            alt_cnes_20hz:comment = "Altitude of satellite above the TOPEX reference
ellipsoid" ;
      short drange_cal(time) ;
            drange_cal:_FillValue = 32767s ;
            drange_cal:long_name = "internal calibration correction to range" ;
            drange_cal:units = "m" ;
            drange_cal:scale_factor = 0.001 ;
            drange_cal:coordinates = "lon lat" ;
            drange_cal:field = 2702s ;
            drange_cal:comment = "Range correction already added to range" ;
      short drange_fm(time) ;
            drange_fm:_FillValue = 32767s ;
            drange_fm:long_name = "Doppler correction to range" ;
            drange_fm:units = "m" ;
            drange_fm:scale_factor = 0.001 ;
            drange_fm:coordinates = "lon lat" ;
```

```
		drange_fm:field = 2704s ;
		drange_fm:comment = "Range correction already added to range" ;
	short flags(time) ;
		flags:_FillValue = 32767s ;
		flags:long_name = "flag word" ;
		flags:flag_masks = 1s, 2s, 4s, 8s, 16s, 32s, 64s, 128s, 256s, 512s, 1024s, 
2048s, 4096s, 8192s, 16384s, -32768s ;
		flags:flag_meanings = "sar_mode not_used continental_ice not_used alt_land 
alt_non_ocean not_used not_used not_used not_used not_used range_suspect 
swh_suspect backscatter_suspect not_used orbit_degraded" ;
		flags:coordinates = "lon lat" ;
		flags:field = 2601s ;
	int range_ku(time) ;
		range_ku:_FillValue = 2147483647 ;
		range_ku:long_name = "Ku-band range corrected for instr. effects" ;
		range_ku:standard_name = "altimeter_range" ;
		range_ku:units = "m" ;
		range_ku:scale_factor = 0.0001 ;
		range_ku:add_offset = 700000. ;
		range_ku:coordinates = "lon lat" ;
		range_ku:field = 601s ;
	int range_20hz_ku(time, meas_ind) ;
		range_20hz_ku:_FillValue = 2147483647 ;
		range_20hz_ku:long_name = "20-Hz Ku-band range corrected for instr. 
effects" ;
		range_20hz_ku:standard_name = "altimeter_range" ;
		range_20hz_ku:units = "m" ;
		range_20hz_ku:scale_factor = 0.0001 ;
		range_20hz_ku:add_offset = 700000. ;
		range_20hz_ku:coordinates = "lon lat" ;
	byte range_used_20hz_ku(time, meas_ind) ;
		range_used_20hz_ku:_FillValue = 127b ;
		range_used_20hz_ku:long_name = "20-Hz flag for utilization in the 
computation of 1-Hz Ku-band range" ;
		range_used_20hz_ku:standard_name = "altimeter_range status_flag" ;
		range_used_20hz_ku:flag_values = 0b, 1b ;
		range_used_20hz_ku:flag_meanings = "yes no" ;
		range_used_20hz_ku:coordinates = "lon lat" ;
		range_used_20hz_ku:comment = "Map of valid points used to compute the 1-Hz 
Ku-band altimeter range, SWH, and sigma0" ;
	short range_rms_ku(time) ;
		range_rms_ku:_FillValue = 32767s ;
		range_rms_ku:long_name = "std dev of Ku-band range" ;
		range_rms_ku:units = "m" ;
		range_rms_ku:scale_factor = 0.0001 ;
		range_rms_ku:coordinates = "lon lat" ;
		range_rms_ku:field = 2002s ;
		range_rms_ku:comment = "Based on valid high-rate measurements" ;
	byte range_numval_ku(time) ;
		range_numval_ku:_FillValue = 127b ;
		range_numval_ku:long_name = "number of valid Ku-band measurements" ;
		range_numval_ku:standard_name = "altimeter_range number_of_observations" ;
		range_numval_ku:units = "1" ;
		range_numval_ku:coordinates = "lon lat" ;
		range_numval_ku:field = 2101s ;
	short swh_20hz_ku(time, meas_ind) ;
		swh_20hz_ku:_FillValue = 32767s ;
```

```
        swh_20hz_ku:long_name = "20-Hz Ku-band significant wave height" ;
        swh_20hz_ku:standard_name = "sea_surface_wave_significant_height" ;
        swh_20hz_ku:units = "m" ;
        swh_20hz_ku:scale_factor = 0.001 ;
        swh_20hz_ku:coordinates = "lon lat" ;
    short swh_ku(time) ;
        swh_ku:_FillValue = 32767s ;
        swh_ku:long_name = "Ku-band significant wave height" ;
        swh_ku:standard_name = "sea_surface_wave_significant_height" ;
        swh_ku:units = "m" ;
        swh_ku:scale_factor = 0.001 ;
        swh_ku:coordinates = "lon lat" ;
        swh_ku:field = 1701s ;
    short swh_rms_ku(time) ;
        swh_rms_ku:_FillValue = 32767s ;
        swh_rms_ku:long_name = "std dev of Ku-band significant wave height" ;
        swh_rms_ku:units = "m" ;
        swh_rms_ku:scale_factor = 0.001 ;
        swh_rms_ku:coordinates = "lon lat" ;
        swh_rms_ku:field = 2802s ;
        swh_rms_ku:comment = "Based on valid high-rate measurements" ;
    short agc_ku(time) ;
        agc_ku:_FillValue = 32767s ;
        agc_ku:long_name = "Ku-band automatic gain control" ;
        agc_ku:units = "dB" ;
        agc_ku:scale_factor = 0.01 ;
        agc_ku:coordinates = "lon lat" ;
        agc_ku:field = 1803s ;
        agc_ku:comment = "AGC setting corrected for individual biases, but not for
drift" ;
    short sig0_20hz_ku(time, meas_ind) ;
        sig0_20hz_ku:_FillValue = 32767s ;
        sig0_20hz_ku:long_name = "20-Hz Ku-band backscatter coefficient" ;
        sig0_20hz_ku:standard_name =
"surface_backwards_scattering_coefficient_of_radar_wave" ;
        sig0_20hz_ku:units = "dB" ;
        sig0_20hz_ku:scale_factor = 0.01 ;
        sig0_20hz_ku:coordinates = "lon lat" ;
    short sig0_ku(time) ;
        sig0_ku:_FillValue = 32767s ;
        sig0_ku:long_name = "Ku-band backscatter coefficient" ;
        sig0_ku:standard_name =
"surface_backwards_scattering_coefficient_of_radar_wave" ;
        sig0_ku:units = "dB" ;
        sig0_ku:scale_factor = 0.01 ;
        sig0_ku:coordinates = "lon lat" ;
        sig0_ku:field = 1801s ;
    short sig0_rms_ku(time) ;
        sig0_rms_ku:_FillValue = 32767s ;
        sig0_rms_ku:long_name = "std dev of Ku-band backscatter coefficient" ;
        sig0_rms_ku:units = "dB" ;
        sig0_rms_ku:scale_factor = 0.001 ;
        sig0_rms_ku:coordinates = "lon lat" ;
        sig0_rms_ku:field = 2902s ;
        sig0_rms_ku:comment = "Based on valid high-rate measurements" ;
    short off_nadir_angle2_wf_ku(time) ;
        off_nadir_angle2_wf_ku:_FillValue = 32767s ;
```

```
        off_nadir_angle2_wf_ku:long_name = "off-nadir pointing angle squared from
waveform" ;
        off_nadir_angle2_wf_ku:units = "degrees^2" ;
        off_nadir_angle2_wf_ku:scale_factor = 0.0001 ;
        off_nadir_angle2_wf_ku:coordinates = "lon lat" ;
        off_nadir_angle2_wf_ku:field = 3002s ;
    short off_nadir_angle2_wf_rms_ku(time) ;
        off_nadir_angle2_wf_rms_ku:_FillValue = 32767s ;
        off_nadir_angle2_wf_rms_ku:long_name = "std dev of off-nadir pointing
angle squared from waveform" ;
        off_nadir_angle2_wf_rms_ku:units = "degrees^2" ;
        off_nadir_angle2_wf_rms_ku:scale_factor = 0.0001 ;
        off_nadir_angle2_wf_rms_ku:coordinates = "lon lat" ;
        off_nadir_angle2_wf_rms_ku:field = 3005s ;
    short attitude_pitch(time) ;
        attitude_pitch:_FillValue = 32767s ;
        attitude_pitch:long_name = "platform pitch angle" ;
        attitude_pitch:units = "degrees" ;
        attitude_pitch:scale_factor = 0.0001 ;
        attitude_pitch:coordinates = "lon lat" ;
        attitude_pitch:field = 3006s ;
    short attitude_pitch_20hz(time, meas_ind) ;
        attitude_pitch_20hz:_FillValue = 32767s ;
        attitude_pitch_20hz:long_name = "20-Hz platform pitch angle" ;
        attitude_pitch_20hz:units = "degrees" ;
        attitude_pitch_20hz:scale_factor = 0.0001 ;
        attitude_pitch_20hz:coordinates = "lon lat" ;
    short attitude_roll(time) ;
        attitude_roll:_FillValue = 32767s ;
        attitude_roll:long_name = "platform roll angle" ;
        attitude_roll:units = "degrees" ;
        attitude_roll:scale_factor = 0.0001 ;
        attitude_roll:coordinates = "lon lat" ;
        attitude_roll:field = 3007s ;
    short attitude_roll_20hz(time, meas_ind) ;
        attitude_roll_20hz:_FillValue = 32767s ;
        attitude_roll_20hz:long_name = "20-Hz platform roll angle" ;
        attitude_roll_20hz:units = "degrees" ;
        attitude_roll_20hz:scale_factor = 0.0001 ;
        attitude_roll_20hz:coordinates = "lon lat" ;
    short attitude_yaw(time) ;
        attitude_yaw:_FillValue = 32767s ;
        attitude_yaw:long_name = "platform yaw angle" ;
        attitude_yaw:units = "degrees" ;
        attitude_yaw:scale_factor = 0.0001 ;
        attitude_yaw:coordinates = "lon lat" ;
        attitude_yaw:field = 3008s ;
    short attitude_yaw_20hz(time, meas_ind) ;
        attitude_yaw_20hz:_FillValue = 32767s ;
        attitude_yaw_20hz:long_name = "20-Hz platform yaw angle" ;
        attitude_yaw_20hz:units = "degrees" ;
        attitude_yaw_20hz:scale_factor = 0.0001 ;
        attitude_yaw_20hz:coordinates = "lon lat" ;
    short off_nadir_angle2_pf(time) ;
        off_nadir_angle2_pf:_FillValue = 32767s ;
        off_nadir_angle2_pf:long_name = "off-nadir pointing angle squared from
platform" ;
```

```
		off_nadir_angle2_pf:units = "degrees^2" ;
		off_nadir_angle2_pf:scale_factor = 0.0001 ;
		off_nadir_angle2_pf:coordinates = "lon lat" ;
		off_nadir_angle2_pf:field = 3004s ;
	byte flags_star_tracker(time) ;
		flags_star_tracker:_FillValue = 127b ;
		flags_star_tracker:long_name = "star tracker flags" ;
		flags_star_tracker:flag_masks = 1b, 2b, 4b ;
		flags_star_tracker:flag_meanings = "str1_on str2_on str3_on" ;
		flags_star_tracker:coordinates = "lon lat" ;
		flags_star_tracker:field = 3413s ;
	short peakiness_20hz_ku(time, meas_ind) ;
		peakiness_20hz_ku:_FillValue = 32767s ;
		peakiness_20hz_ku:long_name = "20-Hz Ku-band peakiness" ;
		peakiness_20hz_ku:units = "1" ;
		peakiness_20hz_ku:scale_factor = 0.01 ;
		peakiness_20hz_ku:coordinates = "lon lat" ;
	short peakiness_ku(time) ;
		peakiness_ku:_FillValue = 32767s ;
		peakiness_ku:long_name = "Ku-band peakiness" ;
		peakiness_ku:units = "1" ;
		peakiness_ku:scale_factor = 0.01 ;
		peakiness_ku:coordinates = "lon lat" ;
		peakiness_ku:field = 2401s ;
	short mqe_20hz_ku(time, meas_ind) ;
		mqe_20hz_ku:_FillValue = 32767s ;
		mqe_20hz_ku:long_name = "20-Hz mean quadratic error of Ku-band waveform
fit" ;
		mqe_20hz_ku:scale_factor = 0.001 ;
		mqe_20hz_ku:coordinates = "lon lat" ;
	short mqe(time) ;
		mqe:_FillValue = 32767s ;
		mqe:long_name = "mean quadratic error of waveform fit" ;
		mqe:scale_factor = 0.001 ;
		mqe:coordinates = "lon lat" ;
		mqe:field = 3409s ;
	short noise_floor_20hz_ku(time, meas_ind) ;
		noise_floor_20hz_ku:_FillValue = 32767s ;
		noise_floor_20hz_ku:long_name = "20-Hz Ku-band noise floor of waveforms" ;
		noise_floor_20hz_ku:units = "dB" ;
		noise_floor_20hz_ku:scale_factor = 0.001 ;
		noise_floor_20hz_ku:add_offset = -20. ;
		noise_floor_20hz_ku:coordinates = "lon lat" ;
	short noise_floor_ku(time) ;
		noise_floor_ku:_FillValue = 32767s ;
		noise_floor_ku:long_name = "Ku-band noise floor of waveforms" ;
		noise_floor_ku:units = "dB" ;
		noise_floor_ku:scale_factor = 0.001 ;
		noise_floor_ku:add_offset = -20. ;
		noise_floor_ku:coordinates = "lon lat" ;
		noise_floor_ku:field = 3411s ;
	short noise_floor_rms_ku(time) ;
		noise_floor_rms_ku:_FillValue = 32767s ;
		noise_floor_rms_ku:long_name = "std dev of Ku-band noise floor of
waveforms" ;
		noise_floor_rms_ku:units = "dB" ;
		noise_floor_rms_ku:scale_factor = 0.001 ;
```

```
		noise_floor_rms_ku:coordinates = "lon lat" ;
		noise_floor_rms_ku:field = 3412s ;
	int range_tracker_20hz_ku(time, meas_ind) ;
		range_tracker_20hz_ku:_FillValue = 2147483647 ;
		range_tracker_20hz_ku:long_name = "20-Hz Ku-band tracker range corrected
for instr. effects" ;
		range_tracker_20hz_ku:standard_name = "altimeter_range" ;
		range_tracker_20hz_ku:units = "m" ;
		range_tracker_20hz_ku:scale_factor = 0.0001 ;
		range_tracker_20hz_ku:add_offset = 700000. ;
		range_tracker_20hz_ku:coordinates = "lon lat" ;
		range_tracker_20hz_ku:comment = "Position of the range window according to
on-board tracker, corrected for internal delays and variations of USO" ;
	short agc_20hz_ku(time, meas_ind) ;
		agc_20hz_ku:_FillValue = 32767s ;
		agc_20hz_ku:long_name = "20-Hz Ku-band automatic gain control" ;
		agc_20hz_ku:units = "dB" ;
		agc_20hz_ku:scale_factor = 0.01 ;
		agc_20hz_ku:coordinates = "lon lat" ;
		agc_20hz_ku:comment = "AGC setting corrected for individual biases, but
not for drift" ;
	int waveform_scale_20hz(time, meas_ind) ;
		waveform_scale_20hz:_FillValue = 2147483647 ;
		waveform_scale_20hz:long_name = "waveform scale factor" ;
		waveform_scale_20hz:units = "dB" ;
		waveform_scale_20hz:scale_factor = 0.001 ;
		waveform_scale_20hz:coordinates = "lon lat" ;
		waveform_scale_20hz:comment = "scale factor (received/transmitted) power,
converted to dB, including instrumental effects" ;
	short waveform_20hz(time, meas_ind, wvf_ind) ;
		waveform_20hz:_FillValue = 32767s ;
		waveform_20hz:long_name = "waveform data" ;
		waveform_20hz:add_offset = 32768. ;
		waveform_20hz:coordinates = "lon lat" ;
	short dry_tropo_ecmwf(time) ;
		dry_tropo_ecmwf:_FillValue = 32767s ;
		dry_tropo_ecmwf:long_name = "ECMWF dry tropospheric correction" ;
		dry_tropo_ecmwf:standard_name =
"altimeter_range_correction_due_to_dry_troposphere" ;
		dry_tropo_ecmwf:source = "ECMWF" ;
		dry_tropo_ecmwf:units = "m" ;
		dry_tropo_ecmwf:scale_factor = 0.0001 ;
		dry_tropo_ecmwf:coordinates = "lon lat" ;
		dry_tropo_ecmwf:field = 701s ;
		dry_tropo_ecmwf:comment = "A dry tropospheric correction must be added to
range to correct for dry troposphere delays" ;
	short wet_tropo_ecmwf(time) ;
		wet_tropo_ecmwf:_FillValue = 32767s ;
		wet_tropo_ecmwf:long_name = "ECMWF wet tropospheric correction" ;
		wet_tropo_ecmwf:standard_name =
"altimeter_range_correction_due_to_wet_troposphere" ;
		wet_tropo_ecmwf:source = "ECMWF" ;
		wet_tropo_ecmwf:units = "m" ;
		wet_tropo_ecmwf:scale_factor = 0.0001 ;
		wet_tropo_ecmwf:coordinates = "lon lat" ;
		wet_tropo_ecmwf:field = 802s ;
```

```
        wet_tropo_ecmwf:comment = "A wet tropospheric correction must be added to
range to correct for wet troposphere delays" ;
    short iono_bent(time) ;
        iono_bent:_FillValue = 32767s ;
        iono_bent:long_name = "Bent ionospheric correction" ;
        iono_bent:standard_name = "altimeter_range_correction_due_to_ionosphere" ;
        iono_bent:source = "Bent climatology" ;
        iono_bent:units = "m" ;
        iono_bent:scale_factor = 0.0001 ;
        iono_bent:coordinates = "lon lat" ;
        iono_bent:field = 902s ;
        iono_bent:comment = "An ionospheric correction must be added to range to
correct for ionosphere delays" ;
    short iono_gim(time) ;
        iono_gim:_FillValue = 32767s ;
        iono_gim:long_name = "JPL GIM ionospheric correction" ;
        iono_gim:standard_name = "altimeter_range_correction_due_to_ionosphere" ;
        iono_gim:source = "JPL GIM 2-hourly maps" ;
        iono_gim:units = "m" ;
        iono_gim:scale_factor = 0.0001 ;
        iono_gim:coordinates = "lon lat" ;
        iono_gim:field = 906s ;
        iono_gim:comment = "An ionospheric correction must be added to range to
correct for ionosphere delays" ;
    short inv_bar_static(time) ;
        inv_bar_static:_FillValue = 32767s ;
        inv_bar_static:long_name = "static inverse barometer correction" ;
        inv_bar_static:standard_name =
"sea_surface_height_correction_due_to_air_pressure_at_low_frequency" ;
        inv_bar_static:source = "ECMWF" ;
        inv_bar_static:units = "m" ;
        inv_bar_static:scale_factor = 0.0001 ;
        inv_bar_static:coordinates = "lon lat" ;
        inv_bar_static:field = 1002s ;
        inv_bar_static:comment = "Effect of the static atmospheric pressure on sea
surface, subtracting global mean" ;
    short inv_bar_mog2d(time) ;
        inv_bar_mog2d:_FillValue = 32767s ;
        inv_bar_mog2d:long_name = "MOG2D dynamic atmospheric correction" ;
        inv_bar_mog2d:source = "CNES/CNRS-LEGOS/CLS MOG2D-G HR barotropic model
with ECMWF forcing" ;
        inv_bar_mog2d:units = "m" ;
        inv_bar_mog2d:scale_factor = 0.0001 ;
        inv_bar_mog2d:coordinates = "lon lat" ;
        inv_bar_mog2d:field = 1004s ;
        inv_bar_mog2d:comment = "Combined low and high frequency effect of
atmospheric pressure and wind on sea surface height" ;
    short tide_solid(time) ;
        tide_solid:_FillValue = 32767s ;
        tide_solid:long_name = "solid earth tide" ;
        tide_solid:standard_name =
"sea_surface_height_amplitude_due_to_earth_tide" ;
        tide_solid:source = "Cartwright, Taylor, Edden" ;
        tide_solid:units = "m" ;
        tide_solid:scale_factor = 0.0001 ;
        tide_solid:coordinates = "lon lat" ;
        tide_solid:field = 1101s ;
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```
          tide_solid:comment = "Calculated using second and third degree
constituents, excluding permanent tide" ;
     int tide_ocean_got00(time) ;
          tide_ocean_got00:_FillValue = 2147483647 ;
          tide_ocean_got00:long_name = "GOT00.2 ocean tide" ;
          tide_ocean_got00:source = "GOT00.2" ;
          tide_ocean_got00:units = "m" ;
          tide_ocean_got00:scale_factor = 0.0001 ;
          tide_ocean_got00:coordinates = "lon lat" ;
          tide_ocean_got00:field = 1207s ;
          tide_ocean_got00:comment = "Ocean tide variation including long-period
equilibrium tides" ;
     short tide_load_got00(time) ;
          tide_load_got00:_FillValue = 32767s ;
          tide_load_got00:long_name = "GOT00.2 load tide" ;
          tide_load_got00:source = "GOT00.2" ;
          tide_load_got00:units = "m" ;
          tide_load_got00:scale_factor = 0.0001 ;
          tide_load_got00:coordinates = "lon lat" ;
          tide_load_got00:field = 1307s ;
          tide_load_got00:comment = "Load tide variation to be added to ocean tide"
;
     short tide_pole(time) ;
          tide_pole:_FillValue = 32767s ;
          tide_pole:long_name = "pole tide" ;
          tide_pole:standard_name = "sea_surface_height_amplitude_due_to_pole_tide"
;
          tide_pole:source = "Wahr [1985]" ;
          tide_pole:units = "m" ;
          tide_pole:scale_factor = 0.0001 ;
          tide_pole:coordinates = "lon lat" ;
          tide_pole:field = 1401s ;
          tide_pole:comment = "Variation of absolute sea level due to polar motion"
;
     short tide_equil(time) ;
          tide_equil:_FillValue = 32767s ;
          tide_equil:long_name = "long-period equilibrium ocean tide" ;
          tide_equil:standard_name =
"sea_surface_height_amplitude_due_to_equilibrium_ocean_tide" ;
          tide_equil:units = "m" ;
          tide_equil:scale_factor = 0.0001 ;
          tide_equil:coordinates = "lon lat" ;
          tide_equil:field = 3901s ;
          tide_equil:comment = "The long-period equilibrium ocean tide is included
in the ocean tide values of the GOT and FES tide models" ;
     short dsig0_atmos_ku(time) ;
          dsig0_atmos_ku:_FillValue = 32767s ;
          dsig0_atmos_ku:long_name = "Ku-band backscatter coefficient correction due
to atmosphere/attitude" ;
          dsig0_atmos_ku:units = "dB" ;
          dsig0_atmos_ku:scale_factor = 0.01 ;
          dsig0_atmos_ku:coordinates = "lon lat" ;
          dsig0_atmos_ku:field = 3203s ;
          dsig0_atmos_ku:comment = "Correction already added to backscatter
coefficient" ;
     short water_vapor_content_gfs(time) ;
          water_vapor_content_gfs:_FillValue = 32767s ;
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        water_vapor_content_gfs:long_name = "NOAA/GFS water vapor content" ;
        water_vapor_content_gfs:standard_name =
"atmosphere_mass_content_of_water_vapor" ;
        water_vapor_content_gfs:source = "NOAA Global Forecast System" ;
        water_vapor_content_gfs:units = "kg/m^2" ;
        water_vapor_content_gfs:scale_factor = 0.01 ;
        water_vapor_content_gfs:coordinates = "lon lat" ;
    short liquid_water_gfs(time) ;
        liquid_water_gfs:_FillValue = 32767s ;
        liquid_water_gfs:long_name = "NOAA/GFS liquid water content" ;
        liquid_water_gfs:standard_name =
"atmosphere_mass_content_of_cloud_liquid_water" ;
        liquid_water_gfs:source = "NOAA Global Forecast System" ;
        liquid_water_gfs:units = "kg/m^2" ;
        liquid_water_gfs:scale_factor = 0.01 ;
        liquid_water_gfs:coordinates = "lon lat" ;
    short wind_speed_alt(time) ;
        wind_speed_alt:_FillValue = 32767s ;
        wind_speed_alt:long_name = "altimeter wind speed" ;
        wind_speed_alt:standard_name = "wind_speed" ;
        wind_speed_alt:source = "altimeter" ;
        wind_speed_alt:units = "m/s" ;
        wind_speed_alt:scale_factor = 0.01 ;
        wind_speed_alt:coordinates = "lon lat" ;
        wind_speed_alt:field = 1901s ;
    short ssb_hyb(time) ;
        ssb_hyb:_FillValue = 32767s ;
        ssb_hyb:long_name = "hybrid sea state bias" ;
        ssb_hyb:standard_name =
"sea_surface_height_bias_due_to_sea_surface_roughness" ;
        ssb_hyb:source = "NOAA/EUMETSAT hybrid model" ;
        ssb_hyb:units = "m" ;
        ssb_hyb:scale_factor = 0.0001 ;
        ssb_hyb:coordinates = "lon lat" ;
        ssb_hyb:field = 1504s ;
    int alt_gdre(time) ;
        alt_gdre:_FillValue = 2147483647 ;
        alt_gdre:long_name = "CNES GDR-E orbital altitude" ;
        alt_gdre:standard_name = "height_above_reference_ellipsoid" ;
        alt_gdre:source = "CNES, GDR-E standards" ;
        alt_gdre:units = "m" ;
        alt_gdre:scale_factor = 0.0001 ;
        alt_gdre:add_offset = 700000. ;
        alt_gdre:coordinates = "lon lat" ;
        alt_gdre:field = 425s ;
        alt_gdre:comment = "Altitude of satellite above the TOPEX reference
ellipsoid" ;
    int alt_eig6c(time) ;
        alt_eig6c:_FillValue = 2147483647 ;
        alt_eig6c:long_name = "ESOC EIGEN-6C orbital altitude" ;
        alt_eig6c:standard_name = "height_above_reference_ellipsoid" ;
        alt_eig6c:source = "ESOC, EIGEN-6C" ;
        alt_eig6c:units = "m" ;
        alt_eig6c:scale_factor = 0.001 ;
        alt_eig6c:coordinates = "lon lat" ;
        alt_eig6c:field = 417s ;
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		alt_eig6c:comment = "Altitude of satellite above the TOPEX reference ellipsoid" ;
	short dist_coast(time) ;
		dist_coast:_FillValue = 32767s ;
		dist_coast:long_name = "distance to coast" ;
		dist_coast:source = "GMT/GSHHS" ;
		dist_coast:units = "km" ;
		dist_coast:coordinates = "lon lat" ;
		dist_coast:field = 4501s ;
		dist_coast:comment = "Negative numbers are inland, positive numbers are offshore" ;
	short inv_bar_mog2d_mean(time) ;
		inv_bar_mog2d_mean:_FillValue = 32767s ;
		inv_bar_mog2d_mean:long_name = "local mean MOG2D dynamic atmospheric correction" ;
		inv_bar_mog2d_mean:source = "MOG2D" ;
		inv_bar_mog2d_mean:units = "m" ;
		inv_bar_mog2d_mean:scale_factor = 0.0001 ;
		inv_bar_mog2d_mean:coordinates = "lon lat" ;
		inv_bar_mog2d_mean:field = 1005s ;
		inv_bar_mog2d_mean:comment = "Long-term temporal mean of the MOG2D dynamic atmospheric correction at measurement location" ;
	short gia(time) ;
		gia:_FillValue = 32767s ;
		gia:long_name = "GIA correction" ;
		gia:source = "ICE5G v1.3 VM2 L90 2012" ;
		gia:units = "m" ;
		gia:scale_factor = 0.0001 ;
		gia:coordinates = "lon lat" ;
		gia:field = 5101s ;
		gia:comment = "Change of land elevation relative to geoid due to GIA since 1 Jan 2000" ;
	int mss_cnescls11(time) ;
		mss_cnescls11:_FillValue = 2147483647 ;
		mss_cnescls11:long_name = "CNES-CLS11 mean sea surface height" ;
		mss_cnescls11:source = "CNES-CLS11" ;
		mss_cnescls11:units = "m" ;
		mss_cnescls11:scale_factor = 0.0001 ;
		mss_cnescls11:coordinates = "lon lat" ;
		mss_cnescls11:field = 1615s ;
	byte basin(time) ;
		basin:_FillValue = 127b ;
		basin:long_name = "basin code" ;
		basin:units = "1" ;
		basin:coordinates = "lon lat" ;
		basin:field = 3601s ;
	int geoid_egm2008(time) ;
		geoid_egm2008:_FillValue = 2147483647 ;
		geoid_egm2008:long_name = "EGM2008 geoid height" ;
		geoid_egm2008:standard_name = "geoid_height_above_reference_ellipsoid" ;
		geoid_egm2008:source = "EGM2008" ;
		geoid_egm2008:units = "m" ;
		geoid_egm2008:scale_factor = 0.0001 ;
		geoid_egm2008:coordinates = "lon lat" ;
		geoid_egm2008:field = 1610s ;
	int mss_cnescls15(time) ;
		mss_cnescls15:_FillValue = 2147483647 ;
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        mss_cnescls15:long_name = "CNES-CLS15 mean sea surface height" ;
        mss_cnescls15:source = "CNES-CLS15" ;
        mss_cnescls15:units = "m" ;
        mss_cnescls15:scale_factor = 0.0001 ;
        mss_cnescls15:coordinates = "lon lat" ;
        mss_cnescls15:field = 1619s ;
    short topo_dtu10(time) ;
        topo_dtu10:_FillValue = 32767s ;
        topo_dtu10:long_name = "DTU10 topography" ;
        topo_dtu10:source = "DTU10" ;
        topo_dtu10:units = "m" ;
        topo_dtu10:coordinates = "lon lat" ;
        topo_dtu10:field = 2205s ;
    int mss_dtu13(time) ;
        mss_dtu13:_FillValue = 2147483647 ;
        mss_dtu13:long_name = "DTU13 mean sea surface height" ;
        mss_dtu13:source = "DTU13" ;
        mss_dtu13:units = "m" ;
        mss_dtu13:scale_factor = 0.0001 ;
        mss_dtu13:coordinates = "lon lat" ;
        mss_dtu13:field = 1616s ;
    int mss_dtu15(time) ;
        mss_dtu15:_FillValue = 2147483647 ;
        mss_dtu15:long_name = "DTU15 mean sea surface height" ;
        mss_dtu15:source = "DTU15" ;
        mss_dtu15:units = "m" ;
        mss_dtu15:scale_factor = 0.0001 ;
        mss_dtu15:coordinates = "lon lat" ;
        mss_dtu15:field = 1618s ;
    int mss_dtu18(time) ;
        mss_dtu18:_FillValue = 2147483647 ;
        mss_dtu18:long_name = "DTU18 mean sea surface height" ;
        mss_dtu18:source = "DTU18" ;
        mss_dtu18:units = "m" ;
        mss_dtu18:scale_factor = 0.0001 ;
        mss_dtu18:coordinates = "lon lat" ;
        mss_dtu18:field = 1621s ;
    int geoid_eigen6(time) ;
        geoid_eigen6:_FillValue = 2147483647 ;
        geoid_eigen6:long_name = "EIGEN6 geoid height" ;
        geoid_eigen6:standard_name = "geoid_height_above_reference_ellipsoid" ;
        geoid_eigen6:source = "EIGEN6c3stat" ;
        geoid_eigen6:units = "m" ;
        geoid_eigen6:scale_factor = 0.0001 ;
        geoid_eigen6:coordinates = "lon lat" ;
        geoid_eigen6:field = 1617s ;
    short topo_srtm30plus(time) ;
        topo_srtm30plus:_FillValue = 32767s ;
        topo_srtm30plus:long_name = "SRTM30_PLUS topography" ;
        topo_srtm30plus:source = "SRTM30_PLUS V10" ;
        topo_srtm30plus:units = "m" ;
        topo_srtm30plus:coordinates = "lon lat" ;
        topo_srtm30plus:field = 2204s ;
    int geoid_xgm2016(time) ;
        geoid_xgm2016:_FillValue = 2147483647 ;
        geoid_xgm2016:long_name = "XGM2016 geoid height" ;
        geoid_xgm2016:standard_name = "geoid_height_above_reference_ellipsoid" ;
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        geoid_xgm2016:source = "XGM2016" ;
        geoid_xgm2016:units = "m" ;
        geoid_xgm2016:scale_factor = 0.0001 ;
        geoid_xgm2016:coordinates = "lon lat" ;
        geoid_xgm2016:field = 1620s ;
    short topo_srtm15plus(time) ;
        topo_srtm15plus:_FillValue = 32767s ;
        topo_srtm15plus:long_name = "SRTM15_PLUS topography" ;
        topo_srtm15plus:source = "SRTM15_PLUS V1" ;
        topo_srtm15plus:units = "m" ;
        topo_srtm15plus:coordinates = "lon lat" ;
        topo_srtm15plus:field = 2209s ;
    byte prox_coast(time) ;
        prox_coast:_FillValue = 127b ;
        prox_coast:long_name = "coastal proximity parameter" ;
        prox_coast:source = "NOC Southampton" ;
        prox_coast:scale_factor = 0.01 ;
        prox_coast:coordinates = "lon lat" ;
        prox_coast:field = 4502s ;
        prox_coast:comment = "Dimensionless measure of the effect of land over
altimetric waveforms, where -1 means unaffected by land (open-ocean) and 1 means
totally affected by land (inla" ;
    byte surface_type(time) ;
        surface_type:_FillValue = 127b ;
        surface_type:long_name = "surface type" ;
        surface_type:source = "GSHHG 2.3.7 coastlines" ;
        surface_type:flag_values = 0b, 1b, 2b, 3b, 4b ;
        surface_type:flag_meanings = "open_ocean unused enclosed_sea_or_lake land
continental_ice" ;
        surface_type:coordinates = "lon lat" ;
        surface_type:field = 2517s ;
    byte surface_class(time) ;
        surface_class:_FillValue = 127b ;
        surface_class:long_name = "surface classification" ;
        surface_class:flag_values = 0b, 1b, 2b, 3b, 4b, 5b, 6b ;
        surface_class:flag_meanings = "open_ocean land continental_water
aquatic_vegetation continental_ice_snow floating_ice salted_basin" ;
        surface_class:coordinates = "lon lat" ;
        surface_class:field = 2518s ;
        surface_class:comment = "Computed from a mask built with MODIS and
GlobCover data" ;
    int tide_ocean_fes04(time) ;
        tide_ocean_fes04:_FillValue = 2147483647 ;
        tide_ocean_fes04:long_name = "FES2004 ocean tide" ;
        tide_ocean_fes04:source = "FES2004" ;
        tide_ocean_fes04:units = "m" ;
        tide_ocean_fes04:scale_factor = 0.0001 ;
        tide_ocean_fes04:coordinates = "lon lat" ;
        tide_ocean_fes04:field = 1213s ;
        tide_ocean_fes04:comment = "Ocean tide variation including long-period
equilibrium and non-equilibrium tides" ;
    short tide_load_fes04(time) ;
        tide_load_fes04:_FillValue = 32767s ;
        tide_load_fes04:long_name = "FES2004 load tide" ;
        tide_load_fes04:source = "FES2004" ;
        tide_load_fes04:units = "m" ;
        tide_load_fes04:scale_factor = 0.0001 ;
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        tide_load_fes04:coordinates = "lon lat" ;
        tide_load_fes04:field = 1313s ;
        tide_load_fes04:comment = "Load tide variation to be added to ocean tide"
;
    int tide_ocean_got48(time) ;
        tide_ocean_got48:_FillValue = 2147483647 ;
        tide_ocean_got48:long_name = "GOT4.8 ocean tide" ;
        tide_ocean_got48:source = "GOT4.8" ;
        tide_ocean_got48:units = "m" ;
        tide_ocean_got48:scale_factor = 0.0001 ;
        tide_ocean_got48:coordinates = "lon lat" ;
        tide_ocean_got48:field = 1219s ;
        tide_ocean_got48:comment = "Ocean tide variation including long-period
equilibrium tides" ;
    short tide_load_got48(time) ;
        tide_load_got48:_FillValue = 32767s ;
        tide_load_got48:long_name = "GOT4.8 load tide" ;
        tide_load_got48:source = "GOT4.8" ;
        tide_load_got48:units = "m" ;
        tide_load_got48:scale_factor = 0.0001 ;
        tide_load_got48:coordinates = "lon lat" ;
        tide_load_got48:field = 1319s ;
        tide_load_got48:comment = "Load tide variation to be added to ocean tide"
;
    int tide_ocean_got410(time) ;
        tide_ocean_got410:_FillValue = 2147483647 ;
        tide_ocean_got410:long_name = "GOT4.10c ocean tide (extrapolated)" ;
        tide_ocean_got410:source = "GOT4.10c (extrapolated)" ;
        tide_ocean_got410:units = "m" ;
        tide_ocean_got410:scale_factor = 0.0001 ;
        tide_ocean_got410:coordinates = "lon lat" ;
        tide_ocean_got410:field = 1222s ;
        tide_ocean_got410:comment = "Ocean tide variation including long-period
equilibrium tides, extrapolated into the coast" ;
    short tide_load_got410(time) ;
        tide_load_got410:_FillValue = 32767s ;
        tide_load_got410:long_name = "GOT4.10 load tide" ;
        tide_load_got410:source = "GOT4.10" ;
        tide_load_got410:units = "m" ;
        tide_load_got410:scale_factor = 0.0001 ;
        tide_load_got410:coordinates = "lon lat" ;
        tide_load_got410:field = 1322s ;
        tide_load_got410:comment = "Load tide variation to be added to ocean tide"
;
    short mss_annual(time) ;
        mss_annual:_FillValue = 32767s ;
        mss_annual:long_name = "annual variation of mean sea level" ;
        mss_annual:source = "DTU10" ;
        mss_annual:units = "m" ;
        mss_annual:scale_factor = 0.0001 ;
        mss_annual:coordinates = "lon lat" ;
        mss_annual:field = 5001s ;
        mss_annual:comment = "Annual variation of sea level with respect to long-
term mean sea level" ;
    int tide_ocean_fes14(time) ;
        tide_ocean_fes14:_FillValue = 2147483647 ;
        tide_ocean_fes14:long_name = "FES2014b ocean tide" ;
```

```
		tide_ocean_fes14:source = "FES2014b (extrapolated)" ;
		tide_ocean_fes14:units = "m" ;
		tide_ocean_fes14:scale_factor = 0.0001 ;
		tide_ocean_fes14:coordinates = "lon lat" ;
		tide_ocean_fes14:field = 1224s ;
		tide_ocean_fes14:comment = "Ocean tide variation including long-period
equilibrium and non-equilibrium tides, extrapolated into the coast" ;
	short tide_load_fes14(time) ;
		tide_load_fes14:_FillValue = 32767s ;
		tide_load_fes14:long_name = "FES2014a load tide" ;
		tide_load_fes14:source = "FES2014a" ;
		tide_load_fes14:units = "m" ;
		tide_load_fes14:scale_factor = 0.0001 ;
		tide_load_fes14:coordinates = "lon lat" ;
		tide_load_fes14:field = 1324s ;
		tide_load_fes14:comment = "Load tide variation to be added to ocean tide"
;
	short tide_non_equil(time) ;
		tide_non_equil:_FillValue = 32767s ;
		tide_non_equil:long_name = "long-period non-equilibrium ocean tide" ;
		tide_non_equil:standard_name =
"sea_surface_height_amplitude_due_to_non_equilibrium_ocean_tide" ;
		tide_non_equil:units = "m" ;
		tide_non_equil:scale_factor = 0.0001 ;
		tide_non_equil:coordinates = "lon lat" ;
		tide_non_equil:field = 3902s ;
		tide_non_equil:comment = "The long-period non-equilibrium ocean tide
results from the corresponding FES tide model and is included in the FES ocean tide
value" ;
	int tide_ocean_webtide(time) ;
		tide_ocean_webtide:_FillValue = 2147483647 ;
		tide_ocean_webtide:long_name = "WebTide ocean tide" ;
		tide_ocean_webtide:source = "WebTide" ;
		tide_ocean_webtide:units = "m" ;
		tide_ocean_webtide:scale_factor = 0.0001 ;
		tide_ocean_webtide:coordinates = "lon lat" ;
		tide_ocean_webtide:field = 1215s ;
		tide_ocean_webtide:comment = "Ocean tide variation including long-period
equilibrium tides" ;
	short ref_frame_offset(time) ;
		ref_frame_offset:_FillValue = 32767s ;
		ref_frame_offset:long_name = "reference frame offset" ;
		ref_frame_offset:units = "m" ;
		ref_frame_offset:scale_factor = 0.0001 ;
		ref_frame_offset:coordinates = "lon lat" ;
		ref_frame_offset:field = 3801s ;
	byte seaice_conc(time) ;
		seaice_conc:_FillValue = 127b ;
		seaice_conc:long_name = "sea ice concentration" ;
		seaice_conc:standard_name = "sea_ice_area_fraction" ;
		seaice_conc:source = "NOAA Optimal Interpolation Sea Surface Temperature
v2" ;
		seaice_conc:units = "%" ;
		seaice_conc:coordinates = "lon lat" ;
		seaice_conc:field = 4701s ;
	short sst(time) ;
		sst:_FillValue = 32767s ;
```

```
        sst:long_name = "sea surface temperature" ;
        sst:standard_name = "sea_surface_temperature" ;
        sst:source = "NOAA Optimal Interpolation Sea Surface Temperature v2" ;
        sst:units = "degC" ;
        sst:scale_factor = 0.01 ;
        sst:coordinates = "lon lat" ;
        sst:field = 4801s ;
    short sst_mean(time) ;
        sst_mean:_FillValue = 32767s ;
        sst_mean:long_name = "local mean sea surface temperature" ;
        sst_mean:source = "NOAA Optimal Interpolation Sea Surface Temperature v2"
;
        sst_mean:units = "degC" ;
        sst_mean:scale_factor = 0.01 ;
        sst_mean:coordinates = "lon lat" ;
        sst_mean:field = 4802s ;
    short dry_tropo_ncep(time) ;
        dry_tropo_ncep:_FillValue = 32767s ;
        dry_tropo_ncep:long_name = "NCEP dry tropospheric correction" ;
        dry_tropo_ncep:standard_name =
"altimeter_range_correction_due_to_dry_troposphere" ;
        dry_tropo_ncep:source = "NOAA/NCEP reanalysis" ;
        dry_tropo_ncep:units = "m" ;
        dry_tropo_ncep:scale_factor = 0.0001 ;
        dry_tropo_ncep:coordinates = "lon lat" ;
        dry_tropo_ncep:field = 702s ;
        dry_tropo_ncep:comment = "A dry tropospheric correction must be added to
range to correct for dry troposphere delays" ;
    short wet_tropo_ncep(time) ;
        wet_tropo_ncep:_FillValue = 32767s ;
        wet_tropo_ncep:long_name = "NCEP wet tropospheric correction" ;
        wet_tropo_ncep:standard_name =
"altimeter_range_correction_due_to_wet_troposphere" ;
        wet_tropo_ncep:source = "NOAA/NCEP reanalysis" ;
        wet_tropo_ncep:units = "m" ;
        wet_tropo_ncep:scale_factor = 0.0001 ;
        wet_tropo_ncep:coordinates = "lon lat" ;
        wet_tropo_ncep:field = 803s ;
        wet_tropo_ncep:comment = "A wet tropospheric correction must be added to
range to correct for wet troposphere delays" ;
    byte dry_tropo_airtide(time) ;
        dry_tropo_airtide:_FillValue = 127b ;
        dry_tropo_airtide:long_name = "air tide correction to the dry tropospheric
correction" ;
        dry_tropo_airtide:units = "m" ;
        dry_tropo_airtide:scale_factor = 0.0001 ;
        dry_tropo_airtide:coordinates = "lon lat" ;
        dry_tropo_airtide:field = 4901s ;
        dry_tropo_airtide:comment = "Add to dry tropospheric correction to account
for missing S1 and S2 tidal signal" ;
    short dry_tropo_era(time) ;
        dry_tropo_era:_FillValue = 32767s ;
        dry_tropo_era:long_name = "ERA dry tropospheric correction" ;
        dry_tropo_era:standard_name =
"altimeter_range_correction_due_to_dry_troposphere" ;
        dry_tropo_era:source = "ECMWF interim reanalysis" ;
        dry_tropo_era:units = "m" ;
```

```
          dry_tropo_era:scale_factor = 0.0001 ;
          dry_tropo_era:coordinates = "lon lat" ;
          dry_tropo_era:field = 709s ;
          dry_tropo_era:comment = "A dry tropospheric correction must be added to
range to correct for dry troposphere delays" ;
     short wet_tropo_era(time) ;
          wet_tropo_era:_FillValue = 32767s ;
          wet_tropo_era:long_name = "ERA wet tropospheric correction" ;
          wet_tropo_era:standard_name =
"altimeter_range_correction_due_to_wet_troposphere" ;
          wet_tropo_era:source = "ECMWF interim reanalysis" ;
          wet_tropo_era:units = "m" ;
          wet_tropo_era:scale_factor = 0.0001 ;
          wet_tropo_era:coordinates = "lon lat" ;
          wet_tropo_era:field = 809s ;
          wet_tropo_era:comment = "A wet tropospheric correction must be added to
range to correct for wet troposphere delays" ;
     short iono_iri2007(time) ;
          iono_iri2007:_FillValue = 32767s ;
          iono_iri2007:long_name = "IRI2007 ionospheric correction" ;
          iono_iri2007:standard_name =
"altimeter_range_correction_due_to_ionosphere" ;
          iono_iri2007:source = "IRI2007 climatology" ;
          iono_iri2007:units = "m" ;
          iono_iri2007:scale_factor = 0.0001 ;
          iono_iri2007:coordinates = "lon lat" ;
          iono_iri2007:field = 907s ;
          iono_iri2007:comment = "An ionospheric correction must be added to range
to correct for ionosphere delays" ;
     short iono_nic09(time) ;
          iono_nic09:_FillValue = 32767s ;
          iono_nic09:long_name = "NIC09 ionospheric correction" ;
          iono_nic09:standard_name = "altimeter_range_correction_due_to_ionosphere"
;
          iono_nic09:source = "NIC09 climatology" ;
          iono_nic09:units = "m" ;
          iono_nic09:scale_factor = 0.0001 ;
          iono_nic09:coordinates = "lon lat" ;
          iono_nic09:field = 908s ;
          iono_nic09:comment = "An ionospheric correction must be added to range to
correct for ionosphere delays" ;
     short swh_ww3(time) ;
          swh_ww3:_FillValue = 32767s ;
          swh_ww3:long_name = "WaveWatch3 significant wave height" ;
          swh_ww3:standard_name = "sea_surface_wave_significant_height" ;
          swh_ww3:units = "m" ;
          swh_ww3:scale_factor = 0.01 ;
          swh_ww3:coordinates = "lon lat" ;
          swh_ww3:field = 1712s ;
     short ssha(time) ;
          ssha:_FillValue = 32767s ;
          ssha:long_name = "sea surface height anomaly" ;
          ssha:standard_name = "sea_surface_height_above_sea_level" ;
          ssha:units = "m" ;
          ssha:scale_factor = 0.0001 ;
          ssha:coordinates = "lon lat" ;
```

```
        ssha:comment = "Sea level from satellite altitude - range - all altimetric
corrections. These values were computed when the data set was created, in contrast
to the sla variable." ;
    short ssha_20hz(time, meas_ind) ;
        ssha_20hz:_FillValue = 32767s ;
        ssha_20hz:long_name = "20-Hz sea surface height anomaly" ;
        ssha_20hz:standard_name = "sea_surface_height_above_sea_level" ;
        ssha_20hz:units = "m" ;
        ssha_20hz:scale_factor = 0.0001 ;
        ssha_20hz:coordinates = "lon_20hz lat_20hz" ;
        ssha_20hz:comment = "Sea level from satellite 20-Hz altitude - range - all
altimetric corrections. These values were computed when the data set was created,
in contrast to the sla_20hz variable." ;
    short wet_tropo_uporto(time) ;
        wet_tropo_uporto:_FillValue = 32767s ;
        wet_tropo_uporto:long_name = "UPORTO wet tropospheric correction" ;
        wet_tropo_uporto:standard_name =
"altimeter_range_correction_due_to_wet_troposphere" ;
        wet_tropo_uporto:source = "UPORTO" ;
        wet_tropo_uporto:units = "m" ;
        wet_tropo_uporto:scale_factor = 0.0001 ;
        wet_tropo_uporto:coordinates = "lon lat" ;
        wet_tropo_uporto:field = 810s ;
        wet_tropo_uporto:comment = "A wet tropospheric correction must be added to
range to correct for wet troposphere delays" ;

// global attributes:
        :Conventions = "CF-1.7" ;
        :title = "RADS 4 pass file" ;
        :institution = "EUMETSAT / NOAA / TU Delft" ;
        :source = "radar altimeter" ;
        :references = "RADS Data Manual, Version 4.2 or later" ;
        :featureType = "trajectory" ;
        :ellipsoid = "TOPEX" ;
        :ellipsoid_axis = 6378136.3 ;
        :ellipsoid_flattening = 0.00335281317789691 ;
        :filename = "c2p0102c049.nc" ;
        :mission_name = "CRYOSAT2" ;
        :mission_phase = "a" ;
        :cycle_number = 49 ;
        :pass_number = 102 ;
        :equator_longitude = 5.625527 ;
        :equator_time = "2013-12-31 22:02:00.865034" ;
        :first_meas_time = "2013-12-31 21:45:51.085914" ;
        :last_meas_time = "2013-12-31 21:47:12.641071" ;
        :original = "L1R (2.06) from L1B (SIR1SAR/4.5) data of 2015-11-27
03:13:48\n",
            "CS_LTA__SIR_SAJ_1B_20131231T214551_20131231T214713_C001.nc" ;
        :log01 = "2019-02-02 | rads_gen_c2_l1r -Sc2 -m -w: RAW data from L1R
(2.06) from L1B (SIR1SAR/4.5) data of 2015-11-27 03:13:48" ;
        :history = "2019-02-02 12:02:59 : rads_gen_c2_l1r -Sc2 -m -w\n",
            "2019-02-02 12:11:07 : rads_add_ncep -Sc2 -gs\n",
            "2019-02-02 12:11:12 : rads_fix_c2 -Sc2 --all\n",
            "2019-02-02 12:11:17 : rads_add_ssb -Sc2 --all\n",
            "2019-02-02 12:11:24 : rads_add_orbit -Sc2 -Valt_gdre --equator --
loc-7 --rate\n",
            "2019-02-02 12:11:31 : rads_add_orbit -Sc2 -Valt_eig6c\n",
```

```
              "2019-02-02 12:11:44 : rads_add_grid -Sc2 -
Vdist_coast,inv_bar_mog2d_mean,gia,mss_cnescls11,basin\n",
              "2019-02-02 12:12:04 : rads_add_grid -Sc2 -
Vgeoid_egm2008,mss_cnescls15\n",
              "2019-02-02 12:12:40 : rads_add_grid -Sc2 -
Vtopo_dtu10,mss_dtu13,mss_dtu15,mss_dtu18\n",
              "2019-02-02 12:13:10 : rads_add_grid -Sc2 -
Vgeoid_eigen6,topo_srtm30plus\n",
              "2019-02-02 12:13:16 : rads_add_grid -Sc2 -Vgeoid_xgm2016\n",
              "2019-02-02 12:14:32 : rads_add_grid -Sc2 -Vtopo_srtm15plus\n",
              "2019-02-02 12:14:40 : rads_add_grid -Sc2 -Vprox_coast\n",
              "2019-02-02 12:14:47 : rads_add_surface -Sc2\n",
              "2019-02-02 12:14:56 : rads_add_surface -Sc2 -s\n",
              "2019-02-02 12:15:20 : rads_add_tide -Sc2 --
models=stide,ptide,fes04,got48,got410,annual\n",
              "2019-02-02 12:17:52 : rads_add_tide -Sc2 --models=fes14,lptide\n",
              "2019-02-02 12:18:38 : rads_add_refframe -Sc2\n",
              "2019-02-02 12:18:45 : rads_add_sst -Sc2 --all\n",
              "2019-02-02 12:19:24 : rads_add_ncep -Sc2 --dry --wet --air\n",
              "2019-02-02 12:23:25 : rads_add_era -Sc2 --dry --wet\n",
              "2019-02-02 12:38:54 : rads_add_ecmwf -Sc2 --all\n",
              "2019-02-02 12:39:09 : rads_add_iono -Sc2 --all\n",
              "2019-02-02 12:41:04 : rads_add_mog2d -Sc2\n",
              "2019-02-02 12:44:44 : rads_add_ww3_222 -Sc2 --all\n",
              "2019-02-02 12:44:51 : rads_add_sla -Sc2\n",
              "2019-02-02 12:45:00 : rads_add_sla -Sc2 --multi-hz\n",
              "2019-02-05 02:47:21 : rads_add_uporto --sat c2/a --all" ;

}
```

6 Wet Troposphere Correction Product Specification

6.1 Introduction

This section describes the wet tropospheric correction (WTC) products to be computed and delivered by UPorto in the scope of the SCOOP project, WP7000. These products can be made available in the project ftp site.

6.2 Brief Algorithm Description

Due to its large spatio-temporal variability, the delay induced by the water vapour and liquid water content of the atmosphere in the altimeter signal or wet tropospheric correction (WTC) is still one of the largest sources of uncertainty in satellite altimetry.

In the scope of SCOOP (WP7000) the University of Porto aims at developing methods and techniques to produce an enhanced WTC for Sentinel-3 (S3), compared to the S3 baseline correction, over the open and coastal ocean. According to the SoW, this WTC shall be based on the combined use of third-party data and evaluated at the S3 orbit space-time sampling.

While S3 data are not available, Envisat data are being used for test purposes (e.g., algorithm development). In addition, the WTC will be computed for the selected CryoSat-2 (CS2) regions of interest (ROI) used in the project.

The reason for using Envisat data and not only CS2 is due to the fact that CS2, unlike S3, does not have any on-board microwave radiometer (MWR), thus not being representative of the S3 measurement conditions. Since S3 possesses a two-channel on-board MWR, similar to that of Envisat, it is expected that both radiometers have similar performances.

The algorithms under development are based on the GNSS-derived Path Delay Plus (GPD+) methodology developed by UPorto in the scope of previous ESA projects (COASTALT, CP4O and SL-cci).

The GPD started as a coastal algorithm, aiming at removing the land effects in the microwave radiometers on board the altimeter missions. Then the methodology evolved to cover the open ocean, including high latitudes, correcting for invalid observations due to land, ice and rain contamination and instrument malfunction.

The most recent version of this algorithm, designated GPD Plus (GPD+), includes the previously designated GPD and DComb (Data Combination) algorithms. The GPD+ are wet path delays based on: i) WTC from the on-board MWR measurements whenever they exist and are valid; ii) new WTC values estimated by data combination, through space-time objective analysis of all available data sources, whenever the previous are considered invalid. In the estimation of the new WTC values, the following data sets are used: valid measurements from the on-board MWR, from water vapour products derived from a set of near 20 scanning imaging radiometers (SI-MWR) on board various remote sensing satellites and wet path delays derived from Global Navigation Satellite System (GNSS) coastal and island stations. In the estimation process, WTC derived from an atmospheric model, such as the European Centre for Medium-range Weather Forecasts (ECMWF) ReAnalysis (ERA) Interim or the operational (Op) model, are used as first guess and adopted values in the absence of measurements.

To ensure consistency and the long term stability of the WTC, the large set of radiometers used in the GPD+ estimations have been inter-calibrated, using the set of Special Sensor Microwave Imager

(SSM/I) and SSMI/I Sounder (SSM/IS) on board the Defense Meteorological Satellite Program satellite series (F10, F11, F13, F14, F16 and F17) as reference, due to their well-known stability and independent calibration.

6.3 Product format

The WTC have been computed for all CS2 L1-B files of the various ROI used in the project and delivered in the netcdf format with the same name with the string “C2_cXXX_pYYYY.nc” added, where XXX is sub-cycle number and YYYY is pass number.

Moreover, when S3 data become available, GPD+ wet tropospheric corrections will be computed and delivered to the project in a similar format.

6.4 Product fields

The following fields are provided

Global attributes:

Cycle - Cycle number as provided in the CS-2/S-3 L1-B files

Orbit - Relative orbit number as provided in the CS-2/S-3 L1-B files

Ascending_Flag **-** Ascending/Descending pass flag

Dimension: Time

Data fields with time dimension:

sub_cycle – sub_cycle number (RADS convention)

pass – pass number(RADS convention)

time – UTC Seconds since 2000-01-01 00:00:00.0+00:00

mjd – modified Julian date (days)

latitude – Latitude (degrees north) as provided in the CS-2/S-3 L1-B files

longitude – Longitude (degrees east) as provided in the CS-2/S-3 L1-B files

wet_GPD – WTC from the GPD+ algorithm (metres)

formal_error – formal error of the wet_GPD estimate (metres)

flag_GPD – wet_GPD validity flag:

0 – point for which the radiometer correction (rad_wet_tropo_cor) is valid - for these points wet_GPD=rad_wet_tropo_cor – not applicable for CryoSat-2;

1 – wet_GPD is a valid estimate;

2 – there were no observations for this point. In this case wet_GPD equals the model value (ERA Interim or ECMWF Op.) – always ECMWF OP for CryoSat-2

3 - unreliable wet_GPD estimate, according to algorithm internal criteria;

4 – wet_GPD was outside the interval [-0.5, 0.0], In this case the values -0.5 and 0.0 were attributed to the correction.

End of the document